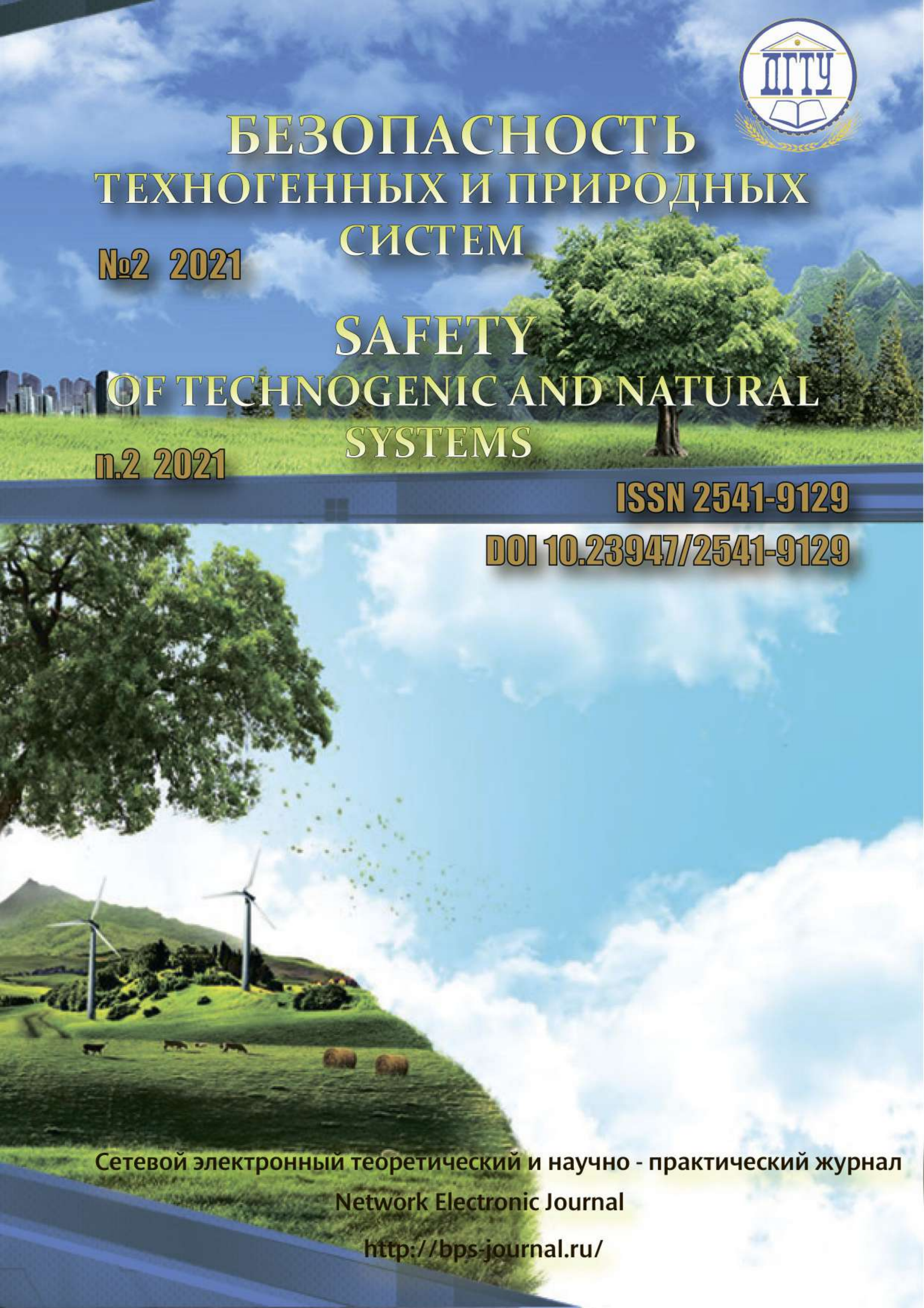


БЕЗОПАСНОСТЬ ТЕХНОГЕННЫХ И ПРИРОДНЫХ СИСТЕМ

№2 2021

SAFETY OF TECHNOGENIC AND NATURAL SYSTEMS

n.2 2021

ISSN 2541-9129

DOI 10.23947/2541-9129

Сетевой электронный теоретический и научно - практический журнал

Network Electronic Journal

http://bps-journal.ru/

CONTENT

LABOR PROTECTION

E. V. Staseva, A. M. Sazonova, V. A. Tukov, P. V. Zadorozhnaya Analysis of typical causes of accidents and injuries at gas supply facilities………………………………………. 2

V. Ya. Manokhin, I. A. Ivanova, E. I. Golovina Methods for determining the effective height of the pipe taking into account the dispersion of emissions in the production facilities working area………………………………………………………………………………... 8

N. Kh. Abdrakhmanov, A. V. Fedosov, N. V. Vadulina, I. S. Kutuzova, L. F. Biktasheva Development of a methodology for assessing professional risks for a drilling enterprise………………………………………………………………………………… 14

O. G. Meretukova, T. A. Shavyrina, E. Yu. Udavtsova, E. V. Bobrinev, A. A. Kondashov Risks of health damage in the units of the Federal Fire-Fighting Service of EMERCOM of the Russian Federation……………………………………………………….. 19

FIRE AND INDUSTRIAL SAFETY

A. A. Korotkiy, Al. An. Demyanov, Al. Al. Demyanov Increasing the safety and operational efficiency of container transportation……………………………………………… 25

ECOLOGICAL SAFETY AND ENVIRONMENT PROTECTION

A. A. Korotkiy, N. N. Nikolaev, G. A. Galchenko, I. V. Yurgin Use of containers-transformers and platooning in megacities — a way to environmental ecology improvement…. 33

L. E. Pustovaya, V. A. Chebysheva Analysis and assessment of the safety level of port facilities using the example of a sulfur storage warehouse…………………………………… 43

S. I. Popov, G. A. Galchenko, Yu. V. Marchenko, D. S. Drozdov Electronic control of the dispatch schedule as means of reduction of emissions of harmful substances by buses…..… 50

UDC 331.45 https://doi.org/10.23947/2541-9129-2021-2-2-7

Analysis of typical causes of accidents and injuries at gas supply facilities

E. V. Staseva[1], A. M. Sazonova[2], V. A. Tukov[1], P. V. Zadorozhnaya[1]

[1]Don State Technical University (Rostov-on-Don, Russian Federation)

[2]Emperor Alexander I St. Petersburg State Transport University (St. Petersburg, Russian Federation)

Introduction. The article considers the problems of industrial injuries and accidents at gas supply facilities. Hazardous production facilities are characterized by an increase in accidents and injuries among workers. The article considers the peculiarities of occurrence of accidents and injuries in the operation of hazardous production facilities.

Problem Statement. The purpose of the study is to analyze the statistics data and the materials of investigation of accidents and emergencies in hazardous industries, to determine the characteristic causes of injuries at work.

Theoretical Part. The statistics on accidents and injuries during operation of gas facilities provided by the Federal State Statistics Service are used as basic information.

Conclusion. The results of the analysis show that the main causes of accidents and emergencies are the causes associated with the human factor and equipment malfunctions. In order to improve safety and prevent injuries among workers, it is necessary to introduce an integrated approach and risk assessment, which will take into account all the factors and conditions that contribute to the occurrence of accidents and injuries at gas supply facilities.

Keywords: accidents, emergencies, gas facilities, safe working conditions.

For citation: Staseva E. V., Sazonova A. M., Tukov V. A., Zadorozhnaya P.V. Analysis of typical causes of accidents and injuries at gas supply facilities; Safety of Technogenic and Natural Systems. 2021;2:2–7. https://doi.org/10.23947/2541-9129-2021-2-2-7

Introduction. The gas industry is the leading branch of the fuel and energy complex of Russia, the main activities of which are the production, transport and storage of natural gas. Every year, the share of gas pipelines in the gas supply system of settlements and enterprises increases. Natural gas is increasingly used in various industries and utilities. One of the most important tasks of the gas industry enterprises is the transportation and accounting of natural gas.

Russia owns one-third of the world's natural gas reserves. Currently, much attention is paid to the development of the gas industry, as gas is a very valuable cost-effective product that can replace other fuels. The use of gas for industrial purposes makes it possible to achieve automation and intensification of production processes, improve sanitary and hygienic working conditions and improve the air basin of the cities of the Russian Federation. At the same time, the operation of gas supply facilities is associated with the risk of accidents at production facilities. According to statistics, the number of accidents and injuries at the production facilities of the gas industry remains quite high [1, 2]. Over the past 3 years, 149 cases of injuries and accidents were registered during the operation of hazardous production facilities of gas supply. The analysis of the research materials shows that the causes of accidents are always different. Identification of the characteristic causes of accidents and injuries at gas supply facilities is an important and urgent task to ensure reliable and trouble-free operation of gas industry enterprises.

Problem Statement. At the moment, the issues of improving the efficiency of the industrial safety and labor protection management system of gas industry enterprises are relevant. Any production facility is characterized by the occurrence of dangerous situations or accidents.

In order to prevent accidents, injuries and improve safety in the operation of gas supply facilities, it is necessary [3]:

- — to create safe working conditions to preserve the life and health of the employees;
- — to reduce the risk of accidents and incidents at hazardous production facilities;
- — to ensure industrial safety during the operation of hazardous production facilities;
- — to develop fire prevention measures.

To achieve this goal, the following tasks were solved:

— statistical data and materials of investigation of accidents and emergencies at hazardous production facilities of gas supply were analyzed;

— the characteristic causes of injuries were identified;

— related causes were identified;

— suggestions were made to solve the identified problems.

Theoretical Part. The analysis of statistics on injuries and accidents at gas supply facilities indicates that the measures taken are not sufficiently effective.

The number of accidents in gas supply organizations over the past 3 years is shown in the diagram (Fig. 1) [4].

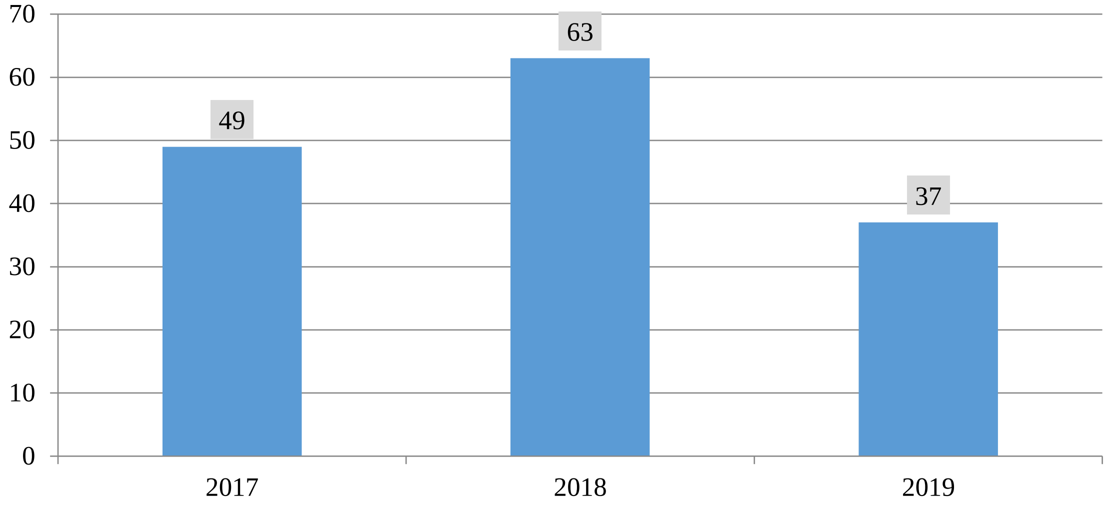


Fig. 1. The number of accidents in gas supply organizations from 2017 to 2019

Over the past 3 years, the lowest number of accidents was observed in 2019, the highest — in 2018. The analysis of the materials of the investigation of these accidents showed that the main causes were [2, 4, 5]:

— deviations from the regulatory requirements of industrial safety in the production of works in the protected zone of gas pipelines;

— insufficiently high level of organization and performance of work to the requirements of safety and labor protection;

— low labor discipline of industrial personnel in the operation of gas supply facilities;

— violation of the requirements of the instructions and safety rules by employees;

— poor quality of training sessions;

— permit-to-work without prior training and verification of knowledge of the requirements for industrial safety in the operation of hazardous production facilities.

There are cases of accidents at gas supply facilities due to aging and wear of equipment, as well as accidents that occur not due to human fault, but due to natural phenomena [6, 7].

The analysis of statistical materials allowed us to determine the characteristic causes of accidents and emergencies at gas supply facilities and to identify the following interrelated groups of causes [8]:

— about 50% of cases are caused by equipment failures (aging and wear);

— the reasons related to the negligence of a person or his inexperience account for more than 43% of cases;

— about 7% of cases are related to external natural causes.

The diagram of the distribution of interrelated groups of causes of accidents and emergencies at gas supply facilities is shown (Fig. 2).

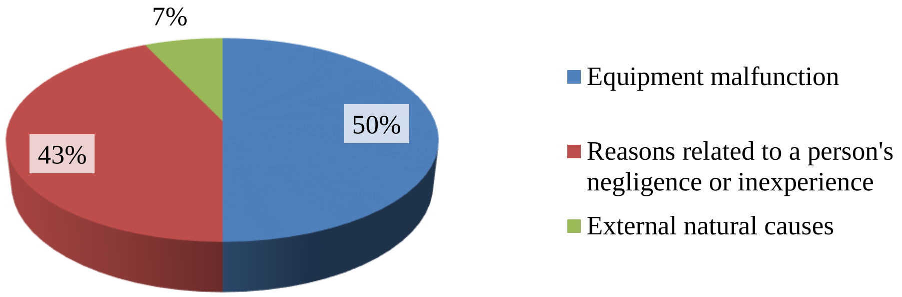


Fig. 2. Interrelated groups of causes of accidents and emergencies at gas supply facilities

Fig. 3 shows the dynamics of the number of fatal accidents from 2017 to 2019. The data analysis shows that 6 people died in 2017, 3 people died in 2018, and 7 people died in 2019. There is an increase in the number of fatal injuries [4, 6].

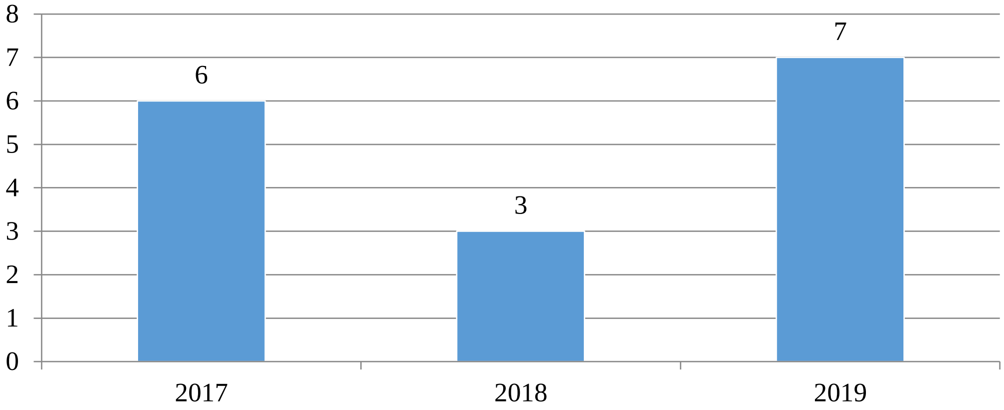


Fig. 3. Number of deaths due to accidents

In 2019, an increase in the number of accident victims was recorded (Fig. 3). At the same time, the number of fires significantly decreased compared to the previous period. The diagram of the number of fires at gas supply facilities is shown in Fig. 4 [1, 4].

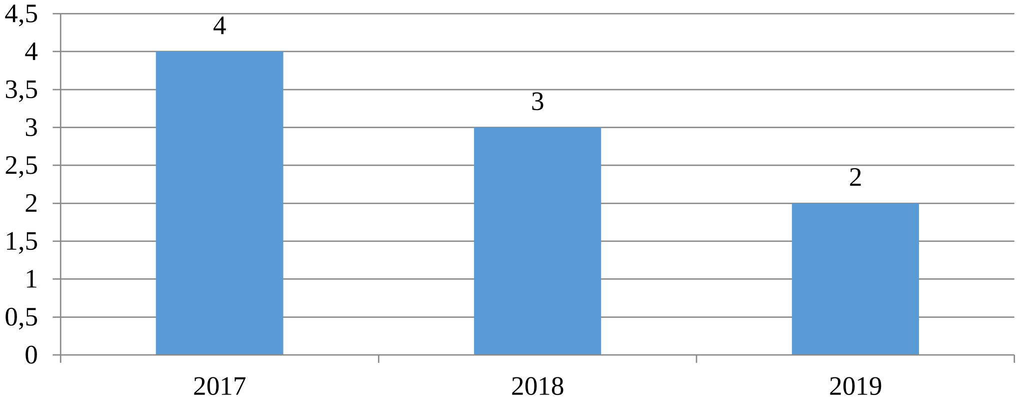


Fig. 4. Number of fires at gas supply facilities

Conclusion. The paper analyzes the statistical data and information on the basis of which the characteristic causes of accidents and injuries at gas supply facilities are established. It also provides the distribution graphs of accidents and emergencies at hazardous production facilities of gas supply.

Based on the analysis, it can be concluded that the causes of injuries and accidents in most cases are of a mixed nature. At the same time, about 50% of accidents occur due to aging, wear and malfunction of equipment, and in 47% of cases, the influence of the human factor is evident. These groups of causes have almost equal shares in their impact on the occurrence of accidents and injuries. Moreover, the issues of timely repair due to malfunctions, analysis of the state of working equipment are solved by the management and maintenance personnel, that is, the influence of the human factor is present everywhere.

Thus, the cause of accidents and injuries is the person himself, as well as the low level of knowledge, poor training, negligence in work or non-compliance with safety measures at work. All this in one way or another leads to an increase in the number of deaths at work [7, 8].

To solve the problems of accidents and injuries at gas supply facilities, it is necessary to develop preventive measures aimed at reducing the influence of the human factor [7]. In this regard, in the authors' opinion, the main thing should be to increase the role of production control, the effectiveness of the training system, and the verification of knowledge of safety and labor protection requirements among workers and specialists [9-10].

It is necessary to change the formalist approach to the training system. The well-coordinated work of the labor protection services of enterprises and specialized training centers, testing of knowledge on labor protection contributes to improving the level of knowledge among employees. It is aimed at reducing occupational injuries.

In order to improve safety and prevent injuries, it is necessary to introduce new forms and methods of organization, conduct production control aimed at timely accounting of all malfunctions and violations in the operation of equipment. It is important to track down all errors in the work of the personnel of the hazardous production facilities of the gas supply system. It is proposed to introduce new technologies, for example, the development of a mobile application that will have all necessary important information, such as routes of safe service passages, a directory of personal protective equipment. In the same application, training and knowledge testing can take place, as well as videos, posters, and slides can be placed. The system should provide for: the possibility of testing knowledge; publication of schedules for medical examinations, current regulations, rules and instructions; the results of a special assessment of working conditions. It is necessary, depending on the specifics of the enterprise, to provide for the possibility of changing the configuration of this application [6, 7, 10]. This will increase the level of awareness of the employees and reduce the impact of the human factor.

As a preventive measure, in order to solve the tasks set, it is necessary to introduce a systematic approach to the development of measures to reduce injuries, including: analyzing and summarizing the results of the investigation materials of both serious accidents, incidents, and all violations of labor safety requirements. In addition, it is important to use an analysis of the state of labor conditions and labor protection based on a risk assessment, which will result in the preparation of risk maps and a summary statement of the state of labor protection of the enterprise. In accordance with them, a set of preventive measures should be developed to improve labor protection and reduce injuries in all identified areas of violations [7-11].

References

1. Analiz tekhnicheskogo sostoyaniya i perspektivy razvitiya gazoraspredelitel'nykh stantsiy OAO "Gazprom" [Analysis of the technical condition and prospects for the development of gas distribution stations of Gazprom OAO]. Draga registrator. URL: https://draga.ru/wp-ontent/uploads/2020/06/gazprom_annual_report_ 2019.pdf (accessed: 22.12.2020). (In Russ.)

2. Staseva E. V. Travmobezopasnot' v gazovom khozyaystve i sosudov pod davleniem. Uchebnoe posobie [Personal injury safety in the gas industry and pressure vessels. Textbook]. Rostov-on-Don: DSTU Publishing center, 2020. 245 p. (In Russ.)

3. STO Gazprom 2-3.5-454-2010. Pravila ekspluatatsii magistral'nykh gazoprovodov [Gazprom company standard 2-3. 5-454-2010. Rules of operation of main gas pipelines]. Moscow: Gazprom OAO Publishing house, 2010. 164 p (In Russ.)

4. Proizvodstvennyy travmatizm [Occupational injuries]. Official website of the Federal State Statistics Service of the Russian Federation. URL: https://rosstat.gov.ru/search?q=proizvodstvennyi+travmatizm (accessed: 19.12.2020). (In Russ.)

5. Prikaz Rostekhnadzora ot 11.04.2016 No. 144 "Ob utverzhdenii Rukovodstva po bezopasnosti "Metodicheskie osnovy po provedeniyu analiza opasnostey i otsenki riska avariy na opasnykh proizvodstvennykh ob’ektakh’ [Rostechnadzor Order No. 144 of 11.04.2016 "On Approval of the Safety Guidelines "Methodological bases for Conducting Hazard Analysis and Accident Risk Assessment at Hazardous Production Facilities"]. Konsul'tantPlyus. URL: http://www.consultant.ru /document/ cons_doc_LAW_196804/ (accessed: 20.12.2020). (In Russ.)

6. Savonin S. V., Moskalenko A. V., Tyunder A. V. et al. Analiz osnovnykh prichin avariy, proizoshedshikh na magistral'nykh gazoprovodakh [Analysis of the main causes of accidents that occurred on the main gas pipelines]. Neft' i Gaz Sibiri. 2015;4(21):32–36. (In Russ.)

7. Sazonova A. M., Staseva E. V. Rol' "chelovecheskogo faktora" v vozniknovenii i razvitii chrezvychainykh situatsiy [Role of the "human factor" in the occurrence and development of emergencies]. Problemy obespecheniya bezopasnosti (Bezopasnost' 2020): mater. II mezhdunar. nauch.-prakt. konf. [Safety Issues (Safety 2020): proc. of the II International scientific and practical conference.]. Ufa, 2020:184–187. (In Russ.)

8. Akimov V. A., Lapin V. L., Popov V. M. et al., Faleeva M. I. (ed) Nadezhnost' tekhnicheskikh sistem i tekhnogennyy risk: ucheb. posobie [Reliability of technical systems and technogenic risk: textbook]. Moscow: Finansovyy izdatel'skiy dom "Delovoy ekspress", 2002. 368 p. (In Russ.)

9. Senchenko V. A., Kaverzneva T. T., Salkutsan V. I. et al. Optimizatsiya obucheniya i proverki znaniy trebovaniy okhrany truda s pomoshch'yu internet-tekhnologiy [Optimization of Training and Check of Knowledge Requirements of Labor Protection by Using Internet Technologies]. Life Safety. 2020;8(236):49–55. (In Russ.)

10. Karaush S. A., Gerasimova O. O. Povyshenie effektivnosti obucheniya rabotnikov stroitel'noy otrasli okhrane truda za schet motivatsii rabotodateley [Increase in the effectiveness in the training of workers in construction branch on the labour protection due to the motivation of employers]. Internet-Vestnik VolgGASU. 2015;1(37):6. URL: http://vestnik.vgasu.ru/attachments/6Karaush Gerasimova-2015_1(37).pdf (accessed: 23.12.2020). (In Russ.)

11. Kvitkina M. V., Staseva E. V., Sazonova A. M. Analiz podkhodov k otsenke professional'nykh riskov [Analysis of Approaches to Occupational Risk Assessment]. Life Safety. 2020;10(238):8–12. (In Russ.).

Submitted 26.03.2021
Scheduled in the issue 08.04.2021

Authors:

Staseva, Elena V., Associate Professor, Department of Occupational Safety, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Cand. Sci., Associate Professor, ORCID: https://orcid.org/0000-0002-8973-9471, elena_staseva@mail.ru

Sazonova, Anna M., Associate Professor, Department of Technosphere and Environmental Safety, Emperor Alexander I St. Petersburg State Transport University (9, Moskovskiy Ave., St. Petersburg, North-Western Federal District, RF, 190031), Cand. Sci., Associate Professor, ORCID: https://orcid.org/0000-0002-9388-978X, amm_2005@mail.ru

Tukov, Vladislav A., Master's degree student, Department of Occupational Safety, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), ORCID: https://orcid.org/0000-0002-9556-9384 tukov_vlad@mail.ru

Zadorozhnaya, Polina V., Master's degree student, Department of Occupational Safety, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), ORCID: https://orcid.org/0000-0002-6596-2556, Zadorozhnaya-polinka@mail.ru

Contribution of the authors:

E. V. Staseva — scientific supervision, analysis of the research results, revision of the text, correction of the conclusions; A. M. Sazonova — preparation of the text, conclusions formulation; V. A. Tukov — formulation of the main concept, goals and objectives of the study, calculations; P. V. Zadorozhnaya — specification of goals and objectives of the study, calculations.

Safety of Technogenic and Natural Systems №2 2021

UDC 504:351.77 https://doi.org/10.23947/2541-9129-2021-2-8-13

Methods for determining the effective height of the pipe taking into account the dispersion of emissions in the production facilities working area

V. Ya. Manokhin, I. A. Ivanova, E. I. Golovina
Voronezh State Technical University (Voronezh, Russian Federation)

Introduction. In order to determine the height of the rise of the polluted substances above the source of the pollution, it is important to know the exact distribution of the gas plume.
Problem Statement. The determination of the dust concentration in the working area of asphalt concrete plants should take into account the assessment of the concentration of harmful substances in the working area of the asphalt concrete plant. The study is the analysis of methods for determining the effective height of the pipe, taking into account the dispersion of emissions in the working area.
Theoretical Part. The paper considers the dependences of the estimation of the initial rise of the gas jet, proposed by Berland, Holland, Briggs, and the specialists of the Tennessee Valley. The value of the initial rise of the impurity jet depends on the moment of the amount of gas movement, the thermal power of the wind speed carrying the jet, and the conditions of thermophoresis. The paper presents the comparative graphs of the calculation of the level of the initial rise of the gas jet at different rates of gas exit from the pipe and constant wind speed.
Conclusion. The method of taking into account the initial rise of the heated gas jet gives us better convergence in the calculations of the maximum surface concentrations of harmful substances and in the estimation of distances to them.

Key words: pollutants, concentration, emission, gas movement, height of the pipe, working area, rise of the jet.

For citation: Manokhin V. Ya., Ivanova I. A., Golovina E. I. Methods for determining the effective height of the pipe taking into account the dispersion of emissions in the production facilities working area; Safety of Technogenic and Natural Systems. 2021;2:8–13. https://doi.org/10.23947/2541-9129-2021-2-8-13

Introduction. Most analytical methods used to calculate the concentrations of harmful substances in emissions from pipes in the working area of production facilities involve the use of a virtual or equivalent source. The study was conducted to determine the virtual point of the beginning of gas dispersion [1-2]. The height of the virtual source is obtained by adding the initial rise of the impurity term Δh, due to the rise of the jet, to the actual height of the pipe h. The phenomenon of the exhaust of a gaseous jet from the pipe into the atmosphere of the working area is mainly determined by three sets of parameters. These include the pipe characteristics, meteorological conditions, and physical and chemical properties of the emission. There are a large number of formulas for determining Δh. Most of them contain arguments determined by the moment of the amount of movement and the thermal lifting force, that is, the first argument is related to the vertical moment of the amount of movement of gases emitted from the pipe, and the second is determined by the difference between the temperature of the gases at the outlet of the pipe and the ambient temperature [3, 4].

Carpenter and others studied the rise of the jet from the pipes of power plants and concluded that the formula proposed by Briggs is preferable for estimating the rise of the jet from the pipes of local power plants [5].

Problem Statement. The emissions coming from the flue and ventilation pipes and openings to the working area have an initial rate of rise and are often overheated relative to the surrounding air. With a light wind, it can be seen that the smoke first spreads almost vertically upwards and then begins to spread horizontally only at some level. Therefore, it is proposed to take into account the initial rise of the impurity ΔH and consider some conditional source located at a higher level (He =H+ДH), usually called the effective height [6, 7].

Theoretical Part. The height of the rise of pollutants above the source of pollution is determined by formula [8]:

$$H_c = H_Г + \Delta h\,,$$

where Hг — the effective height (total) of the gas plume rise, m; Δh — the initial rise of the jet (gas), m.

In the transformed form, this formula, based on empirical data, has the form [8]:

$$\Delta h = \frac{114 \times C \times F^{1/3}}{u}\,, \tag{1}$$

where $F = \dfrac{g \times V_s \times d^2 \times (T_s - T_a)}{4 \times T_a}$, m^4/s^3; g — gravity acceleration, m/s^2; V$_s$ — gas velocity at the outlet of the pipe, m/s; d — diameter of the outlet of the pipe, m; T$_s$ — gas temperature at the outlet of the pipe, ^{0}K; T$_a$ — atmospheric air temperature, ^{0}K; $C = 1{,}58 - 41{,}4 \times \dfrac{\Delta\theta}{\Delta z}$ — dimensionless coefficient; $\dfrac{\Delta\theta}{\Delta z}$ — potential temperature gradient, ^{0}K/m; u — wind speed at the outlet level, m/s. The constant 114 has a dimension of m$^{2/3}$.

The experimental data analysis shows that the rotation of the jet in the conditions of asphalt concrete plants is carried out at altitudes 10 times less than it is determined by the calculation according to formula (1). Therefore, the constant in the Tennessee Valley formula is overestimated by one order, so in further calculations the value of the constant will be taken as 11,4 m$^{2/3}$.

The linear correlation between C and $\dfrac{\Delta\theta}{\Delta z}$ is observed in the range $\dfrac{\Delta\theta}{\Delta z}$ from 0.001 to 0.013 ^{0} K/m.

The formula allows you to calculate the effective value of the rise of the jet over the pipe at a certain distance in the wind direction. The position of the maximum rise of the jet can be significantly shifted away from the pipe in the wind direction. As a result, the dispersion of pollutants in the jet at small distances from the pipe will occur at a height that is less than the effective height H. The results of the method for estimating the effective rise of the jet, depending on the distance x from the pipe, give the dependence Δh in the function x for three conditions of atmospheric stability [9, 10]. For the indifferent stability of the atmosphere ($-0.17 < \dfrac{\Delta\theta}{\Delta z} < 0.16$,where $\dfrac{\Delta\theta}{\Delta z}$ is expressed in ^{0}K/100 m) and a distance of up to 3 000 m [8] the height of the jet rise is calculated by the formula:

$$\Delta h = \frac{2{,}5 \times x^{0{,}56} \times F^{1/3}}{u}\,, \tag{2}$$

where *x* — the distance from the pipe, m.

For high sources, the use of formulas that use Δh in conjunction with x will slightly change the concentration profile. However, such calculations are no longer so reliable when estimating scattering for relatively low sources [11, 12]. Emissions from low-level sources can lead to ground-level concentrations that exceed the permissible level. In addition to the special formulas, taking into account the stability of the atmosphere, a general expression was proposed for the value of the effective rise of the jet [8]:

$$\Delta h = \frac{173 \times F^{1/3}}{u} \times exp\left(0.64 \times \frac{\Delta\theta}{\Delta z}\right), \tag{3}$$

As in the case of formula (1), the analysis of formula (3) and the results of the calculation allowed us to conclude that the coefficient 173 is overstated by one order. In the calculations it will be taken as 17.3.

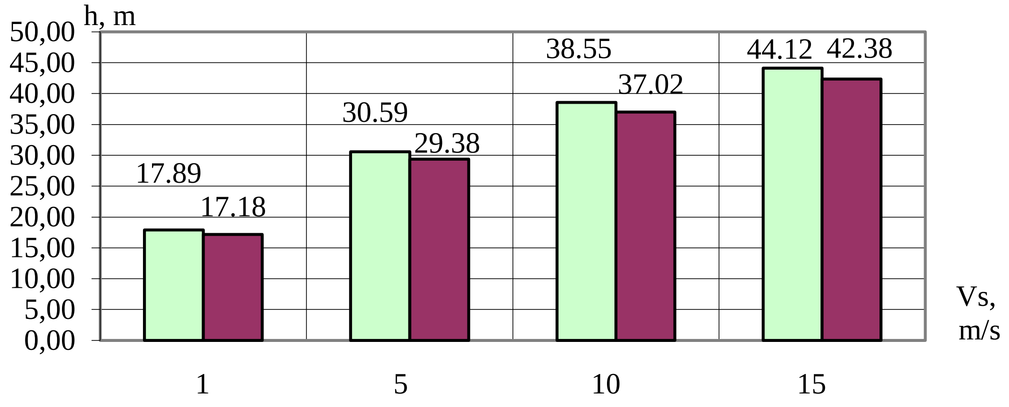


Fig. 1. Comparison graph for calculating the level of the initial rise of the gas jet according to formulas (1) and (3) at different gas exit speeds from the pipe and a constant wind speed (u=1 m/s)

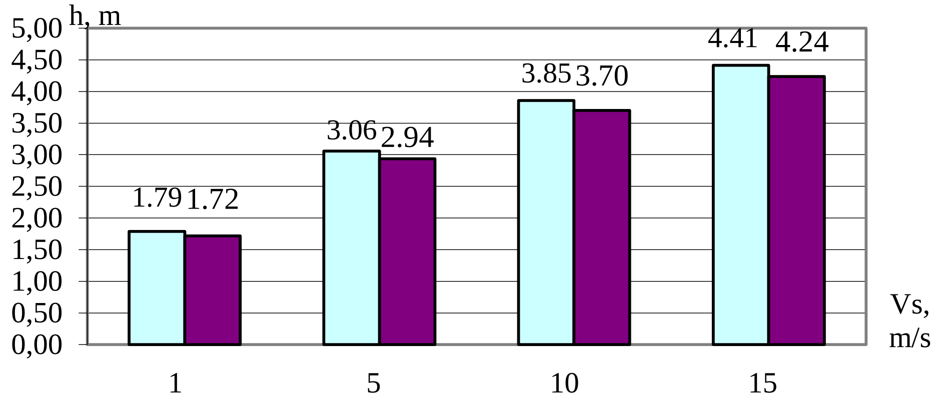


Fig. 2. Comparison graph for calculating the level of the initial rise of the gas jet according to formulas (1) and (3) at different gas exit speeds from the pipe and a constant wind speed (u=10 m/s)

The paper compares the results of calculations using formulas (1) and (3) (Fig. 1 and 2). At the same time, a good convergence of the obtained results was established (the discrepancy of the results does not exceed 5 %). Therefore, in further calculations, we will use only formula (1).

The simplest estimates of Δh are based on the use of some results of the theory of jet propagation in a stationary medium and finding empirical connections between Δh and these factors [13-15].

Further calculations of Δh at different velocities of the jet stream showed the validity of the constant estimate. Table 1 presents the results of calculating the initial rise of a gas jet on the dependencies proposed by Berlanda (2), Holland (3), Briggs (4) and specialists of the Tennessee Valley (1).

The speed of the gas flow from the pipe (W_0=1–15 m/s) and the speed of the air flow that carries away the jet U=1–10 m/s varied in the calculation.

Table 1

Initial rise of the gas jet

U, m/s	W$_0$, m/s	Berland	Holland	Briggs	Tennessee Valley
		$\Delta h = \frac{3{,}58 \times R_0 \times W_0}{U}$m	$\Delta h = \frac{3 \times R_0 \times W_0}{U}$ $+4 \times 10^{-5} \times \frac{Q_t}{U}$m	$\Delta h = 2{,}6 \times \left(\frac{F}{U^3}\right)^{\frac{1}{3}}$ $F_t = \frac{g \times R_0^2 \times W_0 \times \Delta T}{T_a}$m	$\Delta h = \frac{11{,}4 \times C \times F^{\frac{1}{3}}}{u}$m
1	1	3.58	3.384	3.85	17.89
1	5	17.9	15.384	6.59	30.59
1	10	35.8	30.384	8.31	38.54
1	15	53.7	45.384	9.5	44.12
5	1	0.716	0.6768	0.77	3.57
5	5	3.58	3.0768	1.31	6.12
5	10	7.16	6.0768	1.66	7.71
5	15	10.74	9.0768	1.90	8.83
10	1	0.358	0.3384	0.38	1.79
10	5	1.79	1.5384	0.65	3.06
10	10	3.58	3.0384	0.83	3.85
10	15	5.37	4.5384	0.95	4.41
15	1	3.58	3.384	3.85	1.19
15	5	17.9	15.384	6.59	2.04
15	10	35.8	30.384	8.31	2.57
15	15	53.7	45.384	9.51	2.94

$$\Delta h = \frac{3{,}58 \times R_0 \times W_0}{u}, \qquad (4)$$

where R$_0$ — the inner radius of the pipe, m; U — the wind speed on the pipe section, m/s; W$_0$ — the speed of the gas flow flowing out of the pipe, m/s;

$$\Delta h = \frac{3 \times R_0 \times W_0 + 4 \times 10^{-5} \times Q_t}{u}, \qquad (5)$$

where Q — the thermal power of the source, cal/s;

$$\Delta h = 2{,}6 \times \left(\frac{F_t}{u^3}\right)^{1/3}, \qquad (6)$$

where $F_t = \frac{g \times W_0 \times R_0^2 \times \Delta T}{T_a}$

g — the acceleration of gravity, m/s^2; ΔT — the difference between the temperature of the outgoing gas and the ambient air temperature ^{0}C; T$_a$ — the ambient air temperature, ^{0}C.

Conclusion. In this paper, we study four computational models for estimating the height of the jet rise. The authors have refined the estimate of the amount of jet rise above the geometric height of the pipe, depending on various factors: jet momentum, temperature drop. When determining the effective height of the pipe, taking into account the dispersion of emissions in the working area of production, this technique has received a more reliable calculation when assessing the dispersion of harmful substances, which is confirmed by experiments at different speeds of the jet stream.

The validity of this estimate is confirmed by the constants proposed by Berland, Holland, Briggs, and experts from the Tennessee Valley.

References

1. Berlyand M. E. Prognoz i regulirovanie zagryazneniya atmosfery [Forecast and regulation of atmospheric pollution]. Leningrad: Gidrometizdat; 1985. 340 p. (In Russ.).

2. Dubovitskiy D. V., Malyshkin N. G. Vliyanie parametrov istochnika vybrosa zagryaznyayushchikh veshchestv v atmosferu na formirovanie prizemnoy kontsentratsii primesi [Influence of the parameters of the source of emission of pollutants into the atmosphere on the formation of the surface impurity concentration]. Innovatsionnoe razvitie agropromyshlennogo kompleksa dlya obespecheniya prodovol'stvennoy bezopasnosti Rossiyskoy Federatsii: sb. mater. Mezhdunar. nauch.-prakt. konf. [Innovative development of the agro-industrial complex for ensuring food security of the Russian Federation: proc. of the International Scientific and Practical Conference]. 2020;131–136. (In Russ.).

3. Kornyakov A. B., Troitskaya E. V. Raschet kontsentratsii vybrosov vrednykh veshchestv v atmosferu pri nalichii neskol'kikh istochnikov zagryazneniy [Calculating the concentration of harmful emissions into the atmosphere with of several sources of pollution]. Ecological Systems and Devices. 2013;8:12–15. (In Russ.).

4. Lupanov A. P., Gladyshev N. V., Moiseeva N. G. Vybrosy zagryaznyayushchikh veshchestv pri proizvodstve asfal'tobetonnykh smesey i puti ikh snizheniya [Emissions of polluting substances in the production of asphalt mixtures and ways to reduce them]. Advanced Science and Technology for Highways. 2013;4(67):37–38. (In Russ.).

5. Manokhin V. Ya. Nauchno-prakticheskie i metodologicheskie osnovy ekologicheskoy bezopasnosti tekhnologicheskikh protsessov na asfal'tobetonnykh zavodakh: avtoref. dis. … d-ra tekh. nauk [Scientific-practical and methodological bases of ecological safety of technological processes at asphalt-concrete plants: author’s abstract]. Saint-Petersburg, 2004. 42 p. (In Russ.).

6. Manokhin V. Ya., Ivanova I. A. Problemy pozharo-, vzryvoopasnosti na asfal'tobetonnykh zavodakh [Problems of fire and explosion hazards at asphalt concrete plants]. Tekhnicheskie i sotsial'no-gumanitarnye aspekty professional'noy deyatel'nosti GPS MChS Rossii: problemy i perspektivy: sb. tr. IV Mezhdunar. nauch.-prakt. konf. [Technical and socio-humanitarian aspects of the professional activity of the SFFS of the EMERCOM of Russia: problems and prospects: proc. of the IV International Scientific and Practical Conference]. Voronezh: Publishing house of Voronezh Institute of the State Fire Service of the Ministry of Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters of the Russian Federation, 2009, p. 120–124. (In Russ.).

7. Manokhin V. Ya., Ivanova I. A. Osnovnye faktory pozharoopasnosti asfal'tobetonnykh zavodov [Main factors of fire hazard of asphalt concrete plants]. Nauchnyy zhurnal. Inzhenernye sistemy i sooruzheniya. 2009;1(1):17–23. (In Russ.).

8. Manokhin V. Ya., Mushchenko B. L., Karaseva I. A. Opredelenie vysoty pod’ema strui gaza v usloviyakh deystviya snosyashchego potoka vozdukha [Determination of the lifting height of the gas jet under the action of the carrying air flow]. Vysokie tekhnologii v ekologii: sb. tr. 9-oy Mezhdunar. nauch.-prakt. konf. [High technologies in ecology: proc. of the 9th International scientific and practical conference.]. Voronezh: Voronezh State Agrarian University Publishing house, 2006, p. 206–213. (In Russ.).

9. Prikaz Minprirody Rossii ot 06.06.2017 No. 273 "Ob utverzhdenii metodov raschetov rasseivaniya vybrosov vrednykh (zagryaznyayushchikh) veshchestv v atmosfernom vozdukhe" (Zaregistrirovano v Minyuste Rossii 10.08.2017 N 47734) [Order of the Ministry of Natural Resources of the Russian Federation of 06.06.2017 No. 273 "On approval of methods for calculating the dispersion of emissions of harmful (polluting) substances in the atmospheric air" (Registered in the Ministry of Justice of the Russian Federation on 10.08.2017 No. 47734)]. Elektronnyy fond pravovykh i normativno-tekhnicheskikh dokumentov. URL: https://docs.cntd.ru/document/456074826 (accessed 11.02.2021) (In Russ.).

10. Nikolenko S. D., Sazonova S. A., Manokhin V. Ya., Ivanova I. A. Pozharo-, vzryvoopasnost' zhidkikh uglevodorodnykh topliv na asfal'tobetonnykh zavodakh [Fire, explosion hazard of liquid hydrocarbon fuels on asphalt plants]. Systems and Processes Modeling. 2017;10(2):29-33. (In Russ.).

11. Poradek S. V., Tupikin V. M. Puti uluchsheniya ekologicheskoy obstanovki na ABZ [Ways to improve the environmental situation at the asphalt concrete mixing plant]. Dorozhnaya ekologiya XXI veka: tr Mezhdunar. nauch.-prakt. Simpoziuma [Road ecology of the XXI century: proc. of the International sci.-pract. symposium]. Voronezh: Publishing house of VGU–VGASU, 2000. 367 p. (In Russ.).

12. Kuznetsov R. N., Filimonova N. S., Shishkin A. M., Khramovets V. V. Antonov V. P. (ed.), Zrazhevskiy I. M. (ed.) Sbornik zakonodatel'nykh normativnykh i metodicheskikh dokumentov dlya ekspertizy vozdukhookhrannykh meropriyatiy [Collection of legislative regulatory and methodological documents for the examination of air protection measures]. Leningrad: Gidrometizdat Publishing house, 1986 g. — 318 s. (In Russ.).

13. Silkin V. V., Lupanov A. P., Mukhin M. A. Perspektivy primeneniya szhizhennogo gaza [Prospects for the use of liquefied gas]. Stroitel'naya tekhnika i tekhnologii. 2013;3:64–68. (In Russ.).

14. Spolding D. B. Osnovy teorii goreniya [Fundamentals of the combustion theory]. Moscow, 1959. 320 p. (In Russ.).

15. Chekalova L. V. (ed.) Ekotekhnika: Zashchita atmosfernogo vozdukha ot vybrosov pyli, aerozoley i tumanov [Ecotechnics: Protection of atmospheric air from dust, aerosol and fog emissions]. Kholdingovaya gruppa "Kondor Eko–SF NIIOGAZ". Yaroslavl: Rus' Publishing house, 2004. 424 p. (In Russ.).

Submitted 16.03.2021
Scheduled in the issue 07.04.2021

Authors:

Manokhin, Vyacheslav Y., Professor, Department of Technosphere and Fire Safety, Voronezh State Technical University (84, 20-letiya Oktyabrya str., Voronezh, RF, 394006), Dr. Sci., Professor, ORCID: https://orcid.org/0000-0003-4102-5565, manohinprof@mail.ru

Ivanova, Irina A., Associate Professor, Department of Technosphere and Fire Safety, Voronezh State Technical University (84, 20-letiya Oktyabrya str., Voronezh, RF, 394006), Cand. Sci., ORCID: https://orcid.org/0000-0002-2589-3787, ivanova-eco@mail.ru

Golovina, Elena I., Deputy Dean for Academic Affairs, Faculty of Engineering Systems and Structures, Senior Lecturer, Department of Technosphere and Fire Safety, Voronezh State Technical University (84, 20-letiya Oktyabrya str., Voronezh, RF, 394006), ORCID: https://orcid.org/0000-0002-2458-2039 , u00111@vgasu.vrn.ru

Contribution of the authors:

V. Ya. Manokhin — scientific supervision, formulation of the main concept, goals and objectives of the study; I. A. Ivanova — calculations, preparation and presentation the text of the article, work with literature; E. I. Golovina — analysis of the research results, conclusions, correction of the conclusions.

UDC 331.453:622.24 https://doi.org/10.23947/2541-9129-2021-2-14-18

Development of a methodology for assessing professional risks for a drilling enterprise

N. Kh. Abdrakhmanov, A. V. Fedosov, N. V. Vadulina, I. S. Kutuzova, L. F. Biktasheva

Ufa State Petroleum Technological University (Ufa, Republic of Bashkortostan)

Introduction. The article discusses the problems of limited assessment of occupational risk using the existing Fine-Kinney method, which does not take into account the results of a special assessment of working conditions, therefore the authors propose an improved methodology for assessing occupational risk taking into account the working conditions indicator.

Problem Statement. The purpose of this study is to analyze the existing methods of assessing professional risks, analyze the labor protection system at the drilling enterprise, and develop a methodology for assessing professional risks for the drilling enterprise.

Theoretical Part. The existing methods for assessing professional risks and the enterprise standard were used as basic information.

Conclusion. The improved technique will reduce the degree of risk, prevent accidents at work and generally be used at other enterprises.

Keywords: occupational risk, special assessment of working conditions, methods for assessing occupational risks, Fine-Kinney method.

For citation: Abdrakhmanov N. Kh., Fedosov A. V., Vadulina N. V., Kutuzova I. S., Biktasheva L. F. Development of a methodology for assessing professional risks for a drilling enterprise; Safety of Technogenic and Natural Systems. 2021;2:14–18. https://doi.org/10.23947/2541-9129-2021-2-14-18

Introduction. Occupational risk assessment is a mandatory procedure for enterprises. However, to date, there is no approved methodology for occupational risk assessment. To implement this procedure, any risk analysis methods that are most convenient for each individual enterprise can be used.

The approaches used in the occupational risk assessment are similar to those used in the special assessment of working conditions. A special assessment of working conditions also allows you to determine the harmful factors that affect the employee in the working process.

According to the results of a special assessment of working conditions, classes (subclasses) of working conditions in the workplace are formed. There are four such classes in total, and class 4 is the most dangerous [1, 2].

The purpose of this work was to develop a methodology for assessing occupational risks, taking into account the results of a special assessment of working conditions.

Problem Statement. It is necessary to develop and test a methodology suitable for assessing risks at the drilling company's workplaces based on the analysis of the existing methods for professional risks assessment.

The most well-known methods used in occupational risk analysis are the following: the Elmery system method, the brainstorming method, the Delphi method, the matrix method, and the Fine-Kinney method [3-5].

Theoretical Part. Description of risk assessment methods. To solve this problem, the analysis of regulatory documents on the professional risks assessment was carried out (GOST 12.0.230.4–2018, GOST 12.0.230.5–2018, etc.). A brief description of some of the considered methods is presented below

The Elmery system method is based on the use of test sheets and is a visual method of observing working conditions in the workplace [6].

The brainstorming method is based on the consideration of the problem by a group of specialists, the purpose of which is to make the final decision. The main task is to obtain and collect the maximum number of ideas for further analysis [7].

When using **the Delphi method**, experts express their own views anonymously, having the opportunity to find out the views of other experts. This method can be used at any stage of the work on hazard recognition and risk analysis [7].

The matrix method is used for the initial assessment when possible risks are identified. It is necessary to identify the most significant ones for prioritizing their management. The method identifies two extreme risk zones — significantly large and negligibly small degrees of possibility (probability) and degrees of significance (severity). From the point of view of significance, risks can be negligible, acceptable and unacceptable, and probabilities —unlikely, probable and very likely.

Thus, all these methods are not effective enough due to the incompleteness of risk assessment, labor intensity and subjectivity.

As for the methodology for calculating occupational risk using the Fine-Kinney method, the risk assessment is carried out according to the degree of danger in 5 groups and is expressed by the formula [8]:

$$R_{\text{ПР}} = P \cdot V \cdot C \tag{1}$$

where P — the exposure to risk; V — the probability of risk realization; C — the potential damage consequences.

The advantages of this method are the simplicity of calculation, visibility and the possibility of using it at any domestic enterprises.

Suggested solutions. Let us evaluate the professional risk of drilling company employees using the improved Fine-Kinney method. More fully, the risk value can be estimated by changing one indicator in the original formula to another, taking into account the results of the special assessment of working conditions.

The most unfavorable factors of the production environment at the drilling plant are noise, vibration, the severity of the labor process, the chemical factor, as well as dust. Certain employees of the enterprise are assigned the final class of working conditions 3.1 (Table 1) [9-10].

Table 1

Adverse factors affecting oil and gas industry specialists

Profession/position	Name of harmful and/or dangerous production factor	Class of working conditions
Electric and gas welder of the 5 rank	Noise, vibration, chemical factor	3.1
Master of well repair (capital, underground) of the 6 rank	Dust	3.1
Motorist of the cementing of the 6 rank	Severity of the labor process	3.1

Accordingly, taking into account harmful and dangerous production factors, an indicator of working conditions is introduced (replaced by an indicator of risk exposure), which will help to take into account the data of a special assessment of working conditions.

Thus, the improved formula of the Fine-Kinney method for occupational risk assessment will look like this:

$$R_{\text{ПР}} = S \cdot V \cdot C \tag{2}$$

where S — the indicator of working conditions; V — the probability of risk realization; C — the potential damage consequences.

The next step is to draw up the scales of probability, potential damage and the indicator of working conditions presented in table 2.

Table 2

Point scales of the Fine-Kinney method parameters

Risk realization probability scale (V)	Points	Potential damage consequences scale (C)	Points	Working conditions indicator scale (S)	Points
Can be expected	10	Disaster	100	1 (optimal)	1
Is likely to happen	8	Destruction	60	2 (acceptable)	2
Rare, but there is a possibility	6	Pretty much severe	25	3.1	
Impossible	1	Disability	10	3.2 (harmful)	3
Possible, but very unlikely	0,7	Temporary disability	5		4
Impossible in practice	0,2	Minor injury	1	3.3 3.4	5 6
Impossible in real life	0,1	-	-	4 (dangerous)	7

The indicator of working conditions is determined on a point scale from 1 to 7. The probability of risk realization is from 0.1 to 10. Potential damage consequences are from 1 to 100.

The last step is the creation of a numerical designation of risks. They are presented in table 3.

Table 3

Numerical designation of risks

$R_{пр}$	Risk level
0–40	Low risk
41–70	Possible risk
71–120	Serious risk
120–200	High Risk
More than 200	Extremely high risk

Thus, the developed methodology provides an opportunity to fully assess the occupational risk according to the Fine-Kinney method, taking into account the results of a special assessment of working conditions.

Conclusion. In the course of the carried out work, a methodology for professional risks assessment was developed, which was tested on the drilling company employees. With the help of the proposed methodology, it is possible to effectively manage professional risks and achieve their reduction at the drilling enterprise. In the future, this technique can be used at other enterprises to reduce accidents at work.

References

1. Smirnova N. K. Otsenka usloviy truda: ucheb. pos. [Assessment of working conditions: textbook]. Kurgan: Publishing house Kurgan State University, 2019. 188 p. (In Russ.).

2. Rozenfeld E. A. Spetsial'naya otsenka usloviy truda kak element otsenki urovnya professional'nogo riska [Special assessment of working conditions as the element of the occupational risk level evaluation]. Bezopasnost' i okhrana truda. 2020;1:28–29. (In Russ.).

3. Fedosov A. V., Kutuzova I. S., Galimova A. R., Izilyaeva L. O. Analiz normativnykh dokumentov v oblasti otsenki professional'nykh riskov [Analysis of regulatory documents in the field of professional risk assessment]. Eurasian Law Journal. 2020;10(148):423–424. (In Russ.).

4. Abdrakhimov Yu. R., Fedosov A. V., Vadulina N. V. Upravlenie riskami i tekhnicheskoe regulirovanie: monografiya [Risk management and technical regulation: monograph]. Ufa: RITs UGNTU, 2013. 176 p. (In Russ.).

5. Faynburg G. Z. O riskakh zaputat'sya v riskakh pri vyyavlenii, otsenke i upravlenii imi [About risks to get confused in risks at identification, assessment and management of them]. Bezopasnost' i okhrana truda. 2019;1:18–19. (In Russ.).

6. Timofeeva S. S. Sovremennye metody otsenki professional'nykh riskov i ikh znachenie v sisteme upravleniya okhranoy truda [Modern professional risk assessment methods and their role in labor protection management system]. Technosphere Safety. XXI Century. 2016;1(1):14–24. (In Russ.).

7. Kartvelishvili V. M., Sviridova O. A. Risk-menedzhment. Metody otsenki riska: uchebnoe posobie [Risk management. Risk assessment methods: textbook]. Moscow: FGBOU VO «REU im. G. V. Plekhanova», 2017. 120 p. (In Russ.).

8. Bednarzhevskiy S. S., Korol Zh. V. Otsenka professional'nogo riska s pomoshch'yu metoda Faina-Kinni [Professional risk assessment using the Fine-Kinney method]. Science Prospects. 2013;2(43):74–77. (In Russ.).

9. Shcherbakov R. E. Analiz faktorov, okazyvayushchikh vliyanie na zdorov'e rabotnikov burovoi brigady / R. E. Shcherbakov [Analysis of factors affecting the health of drilling crew workers]. Tvorchestvo yunykh — shag v uspeshnoe budushchee. 2015. p. 205–208. (In Russ.).

10. Fedosov A. V., Idrisova K. R., Abdrakhmanov N. Kh. Et al.bPromyshlennaya bezopasnost' pri proizvodstve burovykh rabot: uchebnoe posobie [Industrial safety in drilling operations: textbook]. Sterlitamak: Vektor nauki, 2020. 149 p. (In Russ.)..

Submitted 19.03.2021
Scheduled in the issue 19.04.2021

Authors:

Abdrakhmanov, Nail Kh., Head, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technological University (1, Kosmonavtov st., Ufa, RF, 450062), Dr. Sci., Professor, ORCID: https://orcid.org/0000-0002-3184-1975 , anailx@mail.ru

Fedosov, Artem V., Associate Professor, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technological University (1, Kosmonavtov st., Ufa, RF, 450062), Cand. Sci., ORCID: https://orcid.org/0000-0002-7853-1800 , fedsv-artem@rambler.ru

Badulina, Nadezhda V., Associate Professor, Deputy Head, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technological University (1, Kosmonavtov st., Ufa, RF, 450062), Cand. Sci., ORCID: https://orcid.org/0000-0003-4506-8685, momus7@mail.ru

Kutuzova, Irina S., Master's degree student, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technological University (1, Kosmonavtov st., Ufa, RF, 450062), ORCID: https://orcid.org/0000-0002-3956-1871 , ira.kutuzova.2018@inbox.ru

Biktasheva, Leysan F., Master's degree student, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technological University (1, Kosmonavtov st., Ufa, RF, 450062), ORCID: https://orcid.org/0000-0002-1944-1258 , bik-ley@yandex.ru

Contribution of the authors:

N. Kh. Abdrakhmanov — formulation of the structure of the article, critical analysis, editing; A. V. Fedosov, N. V. Badulina — scientific supervision, formulation of the main goal of the study, development of research methods, processing of the initial observations, text editing; I. S. Kutuzova — statement of the problem, development of the basic research concept; L. F. Biktasheva — participation in the study, collection and analysis of literature data.

UDC 614.84
https://doi.org/10.23947/2541-9129-2021-2-19-24

Risks of health damage in the units of the Federal Fire-Fighting Service of EMERCOM of the Russian Federation

O. G. Meretukova, T. A. Shavyrina, E. Yu. Udavtsova, E. V. Bobrinev, A. A. Kondashov

Federal State Budgetary Institution "All-Russian Order of the "Badge of Honor" Research Institute of Fire Defense of EMERCOM of Russia "(FGBU VNIIPO EMERCOM of Russia) (Balashikha, Russian Federation)

Introduction. Risk assessment is an integral initial stage of the risk management procedure aimed at reducing damage to the health and life of employees. Currently, the legislation does not establish uniform concepts and criteria for assessing occupational risk. Scientific literature presents a variety of approaches and methods for assessing occupational risk from harmful and dangerous factors of industrial activity.

Problem Statement. It is necessary to develop a model for assessing occupational risk in the units of the Federal Fire Service of EMERCOM of Russia, which allows us to take into account the likelihood of harm to the health of an employee as a result of exposure to harmful and (or) dangerous industrial factors and the severity of health disorders as a result of such exposure.

Theoretical Part. For the assessment of occupational risk in the units of the Federal Fire-Fighting Service of EMERCOM of Russia, we take the definition of risk established by the National Standard of the Russian Federation GOST R 12.0.010-2009 "Occupational safety standards system. Occupational safety and health management systems. Hazard and risks identification and estimation of risks". The assessment of the probability of causing harm to the health of an employee was carried out using the following indicators: the frequency of injuries, the frequency of death, the frequency of disability. The severity of health disorder was assessed through the indicator of labor loss by personnel from health damage.

Conclusion. The paper considers various methods for assessing occupational risk from harmful and hazardous factors of industrial activity. A mathematical model is proposed for assessing the risk of health damage in the units of the Federal Fire Service of EMERCOM of Russia on the principle of labor loss by personnel from various types of health damage. Its values were calculated for employees of the Federal Fire Service of EMERCOM of Russia for 2015-2019.

Keywords: risk, damage to health, units of EMERCOM, comprehensive assessment, injuries, disability, death.

For citation: Meretukova O. G., Shavyrina T. A., Udavtsova E. Yu., Bobrinev E. V., Kondashov A. A. Risks of health damage in the units of the Federal Fire-Fighting Service of EMERCOM of the Russian Federation; Safety of Technogenic and Natural Systems. 2021;2:19–24. https://doi.org/10.23947/2541-9129-2021-2-19-24

Introduction. Currently, various methods of occupational risk assessment of harmful and dangerous factors of industrial activity have been developed. However, the legislation still does not establish common concepts and criteria for occupational risk assessment [1-3]. We should note that some definitions of risk do not take into account the severity of damage to an employee as a result of an accident or occupational disease. At the same time, the negative consequences for the health of an employee as a result of an accident can have a different degree of severity — from light damage to health to death. In addition, the damage to the health of the employee may have the character of "deferred harm" and manifest itself after some time [4]. Thus, according to the authors, when calculating the amount of occupational risk for fire protection personnel, it is advisable to take into account the "severity of damage" indicator.

The approaches to assessing occupational risk also differ significantly [5-8].

The national standard of the Russian Federation GOST R 12.0.010-2009 "Occupational safety standards system. Occupational safety and health management systems. Hazard and risks identification and estimation of risks" defines risk as "the combination (product) of the probability (or frequency) of damage and the severity of that damage".

Problem Statement. Taking the latter risk definition as a basis, the task of risk assessment consists of solving two things:

- evaluation of the probability (frequency) of harm to the health of employees as a result of exposure to harmful and (or) hazardous production factors;
- assessment of the severity of health disorder.

To assess the first component, the following risk indicators are used:

- accident frequency coefficient — the number of accidents that occurred in one year per 1000 employees;
- the rate of occurrence of fatal accidents — the number of fatal accidents that occurred in one year per 1000 employees.

The assessment of the second component is given in a general form in GOST R 12.0.010-2009: "In general, when assessing the risk in the workplace, an N-level scale of damage can be used, each level of which is assigned a certain weight coefficient by expert assessment". As an example, a three-level scale of damage severity is given: small, medium, and large.

More precise instructions are given in R 2.2.1766-03 "Guidelines for the assessment of occupational health risks for employees. Organizational and methodological bases, principles and evaluation criteria". When assessing the severity of health disorders, it is recommended to follow Order of the Ministry of Health and Social Development of the Russian Federation No. 160 of February 24, 2005 "On determining the severity of health damage in industrial accidents", according to which industrial accidents are divided into two categories: heavy and light. Signs of a serious accident are injuries that threaten the life of the victim.

Theoretical Part. The proposed model of occupational risk assessment in the units of the Federal Fire Service of the EMERCOM of Russia (FFS EMERCOM of Russia) includes the principle of loss of labor capacity of personnel from various types of health injuries.

The following categories of health injuries were considered:

- fatal or resulting in death within 1 year after an accident in the employment context or as a result of a disease from the group of industrial-related diseases for firefighters [9], in the employment context or within 1 year after leaving the service — 100% loss of labor capacity (247 working days per year);
- accidents that lead to permanent disability after an accident in the employment context or as a result of a disease from the group of industrial-related diseases for firefighters, within 1 year after leaving the service — 100% loss of labor capacity due to the inability to perform official or labor duties (247 working days per year);
- injuries in the employment context that cause temporary disability — the average loss of labor capacity was estimated (the number of days after injuries is about 22 on average) [10].

Microtraumas without disability were not taken into account.

Having used the bank of statistical data on injuries, disabilities and deaths of personnel of the units of EMERCOM of Russia in the performance of official duties [11], the cases of injuries and deaths of personnel of the FFS EMERCOM of Russia in the performance of official duties from 2013 to 2019 were analyzed.

It is proposed to assess professional risks in the units of the Ministry of Emergency Situations (R, nondimensional) as the sum of the risks (per year or over 5 years on average) of health damage multiplied by the corresponding damage severity coefficients calculated for each type of health damage.

$$R = k_t \cdot P_t + k_g \cdot P_g + k_i \cdot P_i \qquad (1)$$

where k_t — the coefficient of severity of injury damage (nondimensional), assumed to be 22/247=0.089; P_t — the frequency of injuries in the performance of official duties, year^{-1}.

$$P_t = \frac{N_t \cdot 1000}{N_{\text{ЛС}}}, \qquad (2)$$

where N_t — the number of injured in the performance of official duties for the reporting year, pers., $N_{\text{ЛС}}$ — the average number of personnel for the reporting year, pers.; k_g — the coefficient of the severity of damage to death (dimensionless), assumed to be 1; P_g — the frequency of death from injuries or due to a disease from the group of industrial-related diseases for firefighters, year^{-1}.

$$P_g = \frac{N_g \cdot 1000}{N_{\text{ЛС}}}, \qquad (3)$$

where N_g — the number of deaths from injuries or due to a disease from the group of industrial-related diseases for firefighters, for the reporting year, pers.; k_i — the coefficient of the severity of damage from disability, dimensionless, assumed to be 1; P_i — the frequency of disability due to an injury or disease from the group of industrial-related diseases for firefighters, year^{-1}.

$$P_i = \frac{N_i \cdot 1000}{N_{\text{ЛС}}}, \qquad (4)$$

where N_i — the number of persons recognized as disabled for the first time due to an injury or a disease from the group of industrial-related diseases for firefighters for the reporting year, pers.

Table 1 presents the main indicators of injuries and deaths of employees of the FFS State Fire Safety Service during their official activities from 2010 to 2019. Due to the lack of representative data on disability of employees of the FFS EMERCOM of Russia for 2016-2019, the average values of the frequency of disability due to injury or disease from the group of industrial-related diseases for firefighters (0.5), obtained in previous years, were used as the components of P_i [11-12].

Table 1

Main indicators of injuries and deaths of employees of the FFS EMERCOM of Russia during their official activities from 2015 to 2019

Year	Frequency of injuries in the performance of official duties	Frequency of deaths from injuries in the performance of official duties	Frequency of deaths due to a disease from the group of industrial-related diseases
2015	1.04	0.07	0.22
2016	0.95	0.15	0.11
2017	0.82	0.05	0.07
2018	0.69	0.06	0.05
2019	1.01	0.08	0.04

Figure 1 shows the results of occupational risk assessment in the units of the FFS EMERCOM of Russia for 2015-2019.

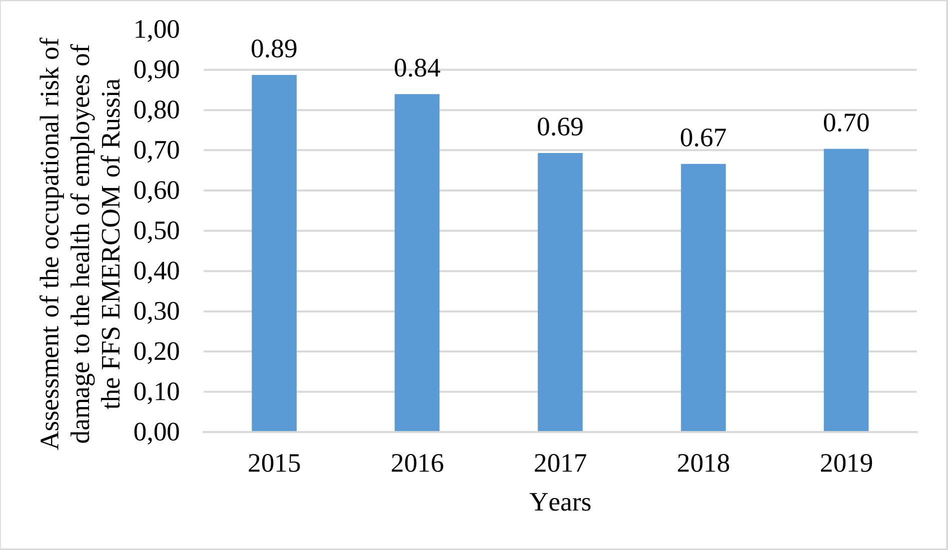


Fig. 1. Results of occupational risk assessment in the units of the FFS EMERCOM of Russia for 2015-2019

As it can be seen from Figure 1, in the last three years, there has been a steady decrease in occupational risk among employees of the FFS EMERCOM of Russia compared to previous years.

Conclusion. Such occupational risk assessments in the departments of the FFS EMERCOM of the Russian Federation should be carried out separately for each identified hazard, as well as for each workplace (position) and the subject of the Russian Federation.

The proposed approach to the occupational risk assessment in the units of the FFS EMERCOM of Russia is more adequate than the used index approach, in which the occupational risks from microtrauma (high probability, rank — 5, low severity of damage, rank — 1) are equal to the occupational risks from death (low probability, rank — 1, high severity of damage, rank — 5). The multiplication of the weight coefficients gives the same value of 5. The obvious disadvantage of index methods is their subjectivity and specificity in relation to individual factors, which is manifested in the risk assessment for individual identified hazards. There is a large group of rare hazards that differ in their frequency by orders, but all of them are assigned the same rank in the probability of occurrence — 1.

It should be noted that for rare identified hazards or for small units where statistically rare health injuries may not occur in the reporting year, continuity corrections should be used to estimate the frequency of health injuries [8].

It should be also emphasized that an occupational risk assessment alone will not bring results. The task is to identify dangerous events that may occur during the service, identify the most dangerous of them and develop correct, balanced, effective measures to ensure the safety of personnel, in order to neutralize these dangers.

References

1. Federal'nyy zakon ot 30.12.2001 No. 197-FZ "Trudovoy kodeks Rossiyskoy Federatsii" [Federal Law No. 197-FZ of 30.12.2001 "Labor Code of the Russian Federation"]. Elektronnyy fond pravovykh i normativno-tekhnicheskikh dokumentov. URL: https://docs.cntd.ru/document/ 901807664 (accessed: 14.04.2021). (In Russ.)

2. Federal'nyy zakon ot 24.07.1998 No. 125-FZ "Ob obyazatel'nom sotsial'nom strakhovanii ot neschastnykh sluchaev na proizvodstve i professional'nykh zabolevaniy" [Federal Law No. 125-FZ of 24.07.1998 "On Compulsory Social Insurance against Industrial Accidents and Occupational Diseases"]. Elektronnyy fond pravovykh i normativno-tekhnicheskikh dokumentov. URL: https://docs.cntd.ru/document/ 901713539 (accessed: 14.04.2021). (In Russ.)

3. Federal'nyy zakon ot 27.12.2002 No. 184-FZ "O tekhnicheskom regulirovanii" [Federal Law No. 184-FZ of 27.12.2002 "On Technical Regulation"] Elektronnyy fond pravovykh i normativno-tekhnicheskikh dokumentov. URL: https://docs.cntd.ru/document/901836556 (accessed: 14.04.2021). (In Russ.)

4. Mashtakov V. A., Kondashov A. A., Bobrinev E. V., Udavtsova E. Yu. Uchet "otlozhennogo vreda" opasnykh proizvodstvennykh faktorov pri strakhovanii zhizni lichnogo sostava pozharnoy okhrany [Accounting for "deferred harm" of hazardous production factors in life insurance of fire protection personnel]. Bezopasnost' i okhrana truda. 2020;3:55–57. (In Russ.)

5. Malyshev D. V. Metod kompleksnoy otsenki professional'nogo riska [Method of comprehensive assessment of occupational risk]. Issues of risk analysis. 2008;5(3):40–59. (In Russ.)

6. Faynburg G. Z. Metody otsenki professional'nogo riska i ikh prakticheskoe primenenie (ot metoda Faina-Kinni do nashikh dney) [Methods of professional risk assessment and their practical application (from the Fine-Kinney method to the present day)] Bezopasnost' i okhrana truda. 2020;2(83):25–41. (In Russ.)

7. Timofeeva S. S. Sovremennye metody otsenki professional'nykh riskov i ikh znachenie v sisteme upravleniya okhranoy truda [Modern professional risk assessment methods and their role in labor protection management system]. Technosphere Safety. XXI Century. 2016;1:14–24. (In Russ.)

8. Matyushin A. V., Poroshin A. A., Shishkov M. V., Bobrinev E. V., Galkina E. Yu. Otsenka professional'nogo riska i obosnovanie neobkhodimogo rezerva chislennosti pozharnykh [Professional risk assessment and justification of the necessary reserve number of firefighters]. Issues of risk analysis. 2009;6(2):6–13. (In Russ.)

9. Marin M. I., Studenikin E. I., Bobrinev E. V., Radionov I. Yu., Sushkina E. Yu. Proizvodstvenno-obuslovlennye zabolevaniya sotrudnikov GPS [Production-related diseases of FFS employees]. Pozharnoe delo. 1999;1:52–54. (In Russ.)

10. Kharin V. V., Bobrinev E. V., Udavtsova E. Yu. Otsenka integral'nogo pokazatelya narusheniy sostoyaniya zdorov'ya lichnogo sostava MChS Rossii [Assessment of the Integral Index of Health Disorders in Russia EMERCOM Personnel]. Medico-Biological and Socio-Psychological Problems of Safety in Emergency Situations. 2018;1:49–56 (In Russ.)

11. Poroshin A. A, Kharin V. V., Bobrinev E. V. et al. Bank statisticheskikh dannykh po zabolevaemosti, travmatizmu, invalidnosti i gibeli lichnogo sostava podrazdeleniy MChS Rossii pri vypolnenii sluzhebnykh obyazannostey [Bank of statistical data on morbidity, injuries, disability and death of personnel of the EMERCOM units of Russia in the performance of official duties]. FGBU VNIIPO MChS Rossii. Elibrary.ru. URL: https://elibrary.ru/item.asp?id=39334955 (accessed: 12.05.2021) (In Russ.)

12. Aleksanin S. S., Evdokimov V. I., Bobrinev E. V., Mukhina N. A. Analiz pokazateley pervichnoy invalidnosti sotrudnikov federal'noy protivopozharnoy sluzhby MChS Rossii i naseleniya Rossii v vozraste 18-44 goda s 2006 po 2015 god [Analysis of indicators of primary disability in employees of the federal fire service of emercom of Russia and the population of Russia aged 18–44 from 2006 to 2015]. Medico-Biological and Socio-Psychological Problems of Safety in Emergency Situations. 2019;1;5–28 (In Russ.)

Submitted 07.04.2021
Scheduled in the issue 19.04.2021

Authors:

Meretukova, Oksana G., Research Associate, All Russian Research Institute for Fire Protection, EMERCOM of Russia (12, md. VNIIPO, Balashikha, Moscow region, RF, 143903), ORCID: https://orcid.org/0000-0002-7397-4864, jrcb2006@yandex.ru

Shavyrina, Tatyana A., Leading Research Associate, All Russian Research Institute for Fire Protection, EMERCOM of Russia (12, md. VNIIPO, Balashikha, Moscow region, RF, 143903), Cand. Sci., ORCID: https://orcid.org/0000-0003-1158-2141 , shavyrina@mail.ru

Udavtsova, Elena Yu., Senior Research Associate, All Russian Research Institute for Fire Protection, EMERCOM of Russia (12, md. VNIIPO, Balashikha, Moscow region, RF, 143903), Cand. Sci., ORCID: https://orcid.org/0000-0002-1343-0849, otdel_1_3@mail.ru

Bobrinev, Evgeniy V., Leading Research Associate, All Russian Research Institute for Fire Protection, EMERCOM of Russia (12, md. VNIIPO, Balashikha, Moscow region, RF, 143903), Cand. Sci., ORCID: https://orcid.org/0000-0001-8169-6297 , otdel_1_3@mail.ru

Kondashov, Andrey A., Leading Research Associate, All Russian Research Institute for Fire Protection, EMERCOM of Russia (12, md. VNIIPO, Balashikha, Moscow region, RF, 143903), Cand. Sci., ORCID: https://orcid.org/0000-0002-2730-1669 , akond2008@mail.ru

Contribution of the authors

O. G. Meretukova — review of publications on the topic of the article, participation in the collection and processing of the material, participation in the writing of the text of the manuscript, editing and revision of the text; T. A. Shavyrina — participation in the collection and processing of the material, participation in the writing of the text of the manuscript, design of the final version of the article; E. Yu. Udavtsova — development of the design of the study, preparation of literature, participation in the collection and processing of the material, participation in the writing of the text of the manuscript; E. V. Bobrinev — formulation of the main idea and concept of the research, scientific guidance, analysis of the results of the research, participation in writing of the text of the manuscript, correction of the conclusions; A. A. Kondashov — development of the purpose and objectives of the research, calculations, analysis and interpretation of data, formulation of the conclusions, participation in writing the text of the manuscript.

UDC 621.86 https://doi.org/10.23947/2541-9129-2021-2-25-32

Increasing the safety and operational efficiency of container transportation

A. A. Korotkiy, Al. An. Demyanov, Al. Al. Demyanov

Don State Technical University (Rostov-on-Don, Russian Federation)

Introduction. Currently, there is a logistic problem in container transportation technology related to the transportation of empty freight containers, as returnable containers, since an empty container takes up as much space as a full one. A promising direction for solving this problem is the introduction of folding cargo containers. A disadvantage of this approach is the likelihood of injury to the maintenance personnel, which must be inside in the process of folding and unfolding.

Problem Statement. The objective of this study is to study the conditions for increasing the safety of preparatory work due to the design of the container, the main feature of which is the ability to realize the effect of functional self-adaptation to working conditions.

Theoretical Part. This approach allows us, when folding and unfolding, to balance the changing reactions from the own masses and the moments of its moving body parts by means of the corresponding lockable gas springs. Gas springs connect leading links and driven kinematic chains thereby ensuring that their movement in a given speed mode on the entire trajectory is independent of the speed of the driving link. For the practical implementation of the proposed design solution, the paper presents a general method for the synthesis of an adaptive controller of the container mechanisms in the process of folding and unfolding its moving parts.

Conclusion. Testing of the container showed that the effect of functional self-adaptability is quite well implemented along the entire trajectory of the container elements without the use of external lifting mechanisms.

Keywords: folding container, safety increase, self-adaptability, adaptive management.

For citation: Korotkiy A. A., Demyanov Al. An., Demyanov Al. Al. Increasing the safety and operational efficiency of container transportation; Safety of Technogenic and Natural Systems. 2021;2:25–32. https://doi.org/10.23947/2541-9129-2021-2-25-32

Introduction. Currently, there is a logistical problem in container transportation technology related to the transportation of empty containers as returnable containers. Given that an empty container takes up as much space as a loaded container, their transportation by vehicles significantly increases fuel costs, unproductive labor costs, depreciation of vehicles, traffic congestion and negative environmental impact.

Problem Statement. One of the most promising ways to solve this complex problem, which opens up the possibility of getting out of this situation, is the introduction of folding cargo containers. The folding design of the container can provide transportation of several empty assembled containers in one vehicle, allowing you to save logistics and transport costs due to more efficient organization of transportation [1].

To date, a number of design versions [2] of collapsible cargo containers-transformers are known. The main structural and kinematic features of this type of transformers are the presence of an upper and lower base, folding side and end walls. Moreover, the walls located in the end part, as well as the upper and lower bases, consist of parts attached by means of hinges to the side walls. In this case, the parts of the bases are also connected to each other by means of hinged joints. To avoid deformation of the parts of the upper base in the process of transformation, they are equipped with stops. The side walls are pivotally connected to the bases, at the corners of which there are elements for slinging. The design is based on these elements when assembled. The mounting elements are also installed on the end walls, both on the outside and on the inside.

A characteristic disadvantage of this type of construction is the need to use lifting devices for folding and unfolding, which significantly reduces their operational efficiency. In addition, a very serious disadvantage is that there is a possibility of injury to the maintenance personnel, since when performing folding and unfolding operations, such a structure requires the maintenance personnel to be inside the container.

In the current situation, the need to improve the operational efficiency of folding cargo containers is obvious. Based on the stated shortcomings, one of the directions that allow us to solve this problem is the development of an autonomous and more efficient design of a folding container. In particular, an increase in the operational efficiency of the structure can be achieved by including mechanisms that allow it to be brought into the working position and back without the use of external lifting mechanisms, thereby ensuring the safety of maintenance personnel [3].

Theoretical Part. As a solution to this problem, we propose the design of a folding container, the mechanisms of which allows us to realize the effect of functional self-adaptability (adaptation) to working conditions [2]. The implementation of this approach makes it possible, when folding and unfolding, to balance the total natural masses and moments from the moving body parts (roof, side and end walls) by means of an appropriate blocked gas spring and to ensure their movement in a given speed mode throughout the entire trajectory, regardless of the speed of the leading link. In other words, a more uniform, "smooth" speed mode is provided in relation to the leading link, which, in turn, also increases the level of safety during operation.

Let us consider the operation of such a container on the example of its use for the transportation of piece goods in the cramped conditions of urban environment. Folding cargo containers in the folded state can be stored in the warehouse in stacks, like any large-sized cargo. If necessary, with the help of a car manipulator by the spreader, the containers are slung and loaded into the body or on the platform of the car on top of each other and then secured. The manipulator with containers is sent along the route. Arriving at the loading site, for example, the yard of a residential building, the manipulator is used to unload the folded container to an empty space (Fig. 1).

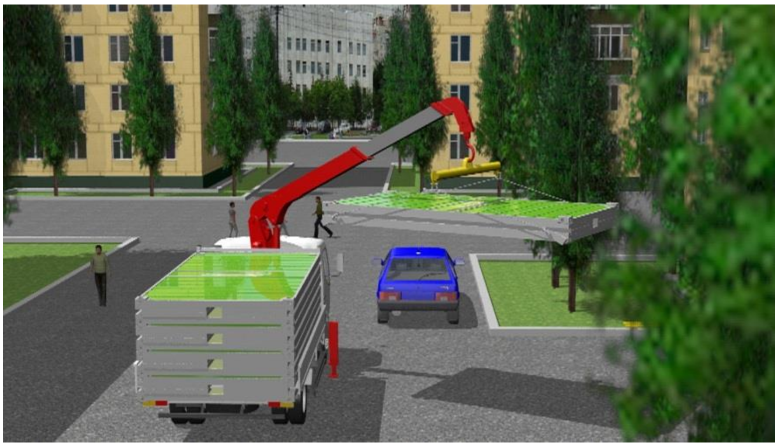


Fig. 1. Unloading of a folded collapsible cargo container

In a folded state, such a container occupies a minimum space, approximately one quarter of its volume in the opened state.

After unloading the container (Fig. 2), the operator uses the manual lever 1 through the holes 2 in the frame to unfold the side walls by engaging first with the system of levers and wings 3 of the side gas spring 4, and then with the system of levers and links 5 of the end gas spring 6. By means of the same manual lever 1, a force is created in the direction of both folding and unfolding. The generated force is necessary to press the spring-loaded buttons, which are located respectively in the end part of the rod 8 of the side lockable gas spring 4 and the end part of the rod 9 of the end lockable gas spring 6. After opening the side walls with the lever 1 through the hole 10, the end walls are similarly laid out. After the container is fully assembled, the keys to the sectional gate 11 are given to the customer, and the manipulator with the operator leaves.

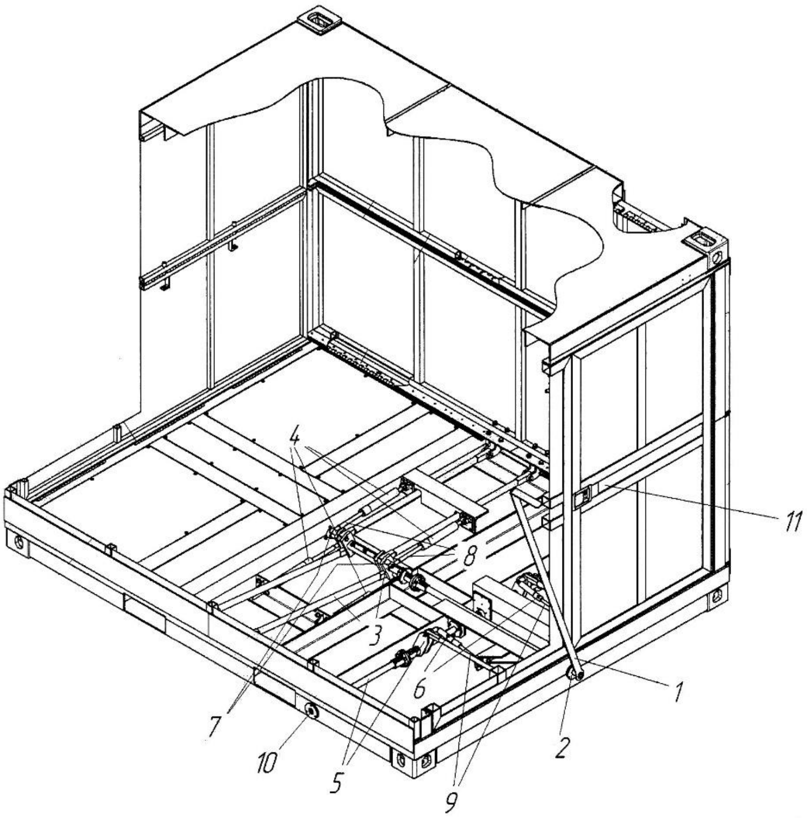


Fig. 2. Main structural components of a collapsible cargo container

After loading the container with individual cargo, the customer closes it and informs the operator about the need to move it. To do this, an empty manipulator arrives, loads the container into the body of the car and moves it to the final destination. Upon arrival, the operator uses a manipulator to remove the container from the car to the agreed place.

The customer unloads the container and informs the operator about the need to transport an empty container. The operator, in the reverse order, by means of the manual lever 1 (Fig. 3), folds the container, slings it and loads it into the car body, which moves the folded containers to the warehouse (base), where they are stacked.

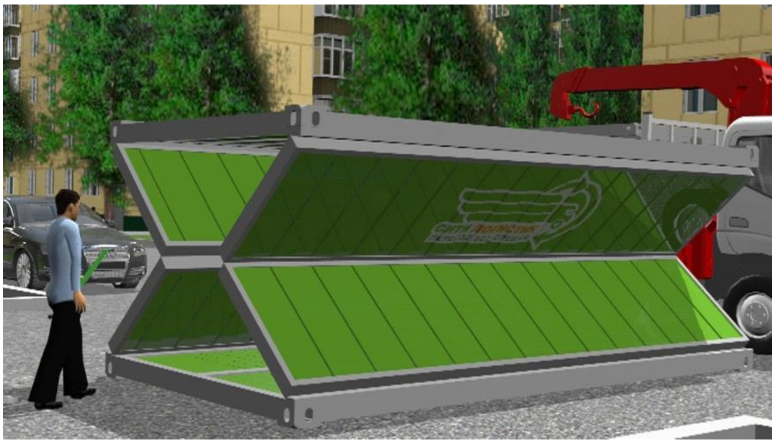


Fig. 3. The process of unfolding and folding the container

Based on the description of the principle of operation of a folding cargo container, it is obvious that the main feature of such a mechanism should be the ability to balance the changing reactions from its own masses and moments of its movable body elements (roof, side and end walls) in the process of folding and unfolding. To implement such a feature, it is necessary to have an idea of the behavior of the designed mechanical system in real conditions. For ease of analysis, the systems are divided into mutable and immutable, but in real life, all systems are mutable. Their changes are caused by the laws of nature. Since this mechanical system refers to objects that have a geometric shape and mass, its adaptability will be subject to the law of least resistance [4]. This law is called the Hamilton principle, according to which the system itself chooses the option of moving from one position to another in the direction of reducing the potential energy with the least loss.

In relation to the described case, when folding and unfolding the container, there is no complete kinetostatic and dynamic picture describing the relationship and interaction of the driving forces and their moments changing in the process of folding and unfolding with the forces and moments of the resistance forces. In such cases, the change in the system control parameters is formulated directly from the control goals, for which it is most appropriate to use functional-adaptive control methods [4, 5].

Solution to this type of problem applied to adaptive systems is known as the "adaptive controller synthesis" procedure. To build an adaptive controller of a node, it is necessary to determine the parameters in the form of "input-output" [6].

From the description of the design and operation of the container mechanisms, it follows that their power and speed characteristics change during the opening process and, therefore, the algorithm of operation of such a controller will have to adapt to the changing parameters of the object during its operation.

Let us consider in general the process of constructing adaptive mechanical systems using the equation of the control vector of perturbed (real) motion for subsequent application to the leading and driven kinematic chains of the container [7, 8]:

$$\dot{X} = \phi(x,u,t) \quad (1)$$

where (t)— n - dimensional vector of variable states of the object; $u(t)$— m- dimensional vector of control; t — the time of the operation of the object.

Let us present equation (1) in the expanded form:

$$\frac{dx}{dt} = \phi_i(x_1,...,x_n,\ u_1...u_m,\ t),\ (i=1,\ n) \quad (2)$$

where $\varphi_i(x_1,...,x_n,\ u_1...u_m,\ t)\cdot(i=1,\ n)$ — the given functions that are assumed to be continuous and differentiable by the required number of times $x_1,...,x_n,\ u_1...u_m,\ t$.

In the original equation (1), both the control parameters and the object state parameters are the functions, the nature of change of which over time is unknown, but can be determined from the following conditions. The initial ($x^{(0)}$) and final ($x^{(1)}$)states of the object (1) are set:

$$x(t_0)=x^{(0)} \tag{3}$$

$$x(t_1)=x^{(1)} \tag{4}$$

where t_0 — the time of the beginning of the operation of the object; t_1 — the time of the end of the operation of the object.

The control efficiency is estimated using the integral:

$$\gamma=\int_{t_0}^{t_1}\phi_0(x,\ u,\ t)dt\ , \tag{5}$$

where $\varphi_0(x,\ u,\ t)dt$ — the given continuous function of its arguments.

When solving this problem, we take a decrease in the value of this integral as an increase in the efficiency of control. Next, we take into account the restrictions on the parameter of the state and control variables, and then express through these restrictions the permissible limits of the control resource and the permissible limits of changing the state variables:

$$|u_k(t)|\le u_k^*\ (k=1,\ m)\ , \tag{6}$$

where $u_k^*(k=1,\ m)$ — the specified numbers.

Taking into account the kinematic and design features of the container mechanisms (control objects) and the operating conditions (state variables) in the described case, we define a bounded set u in the space of variables $u_1,...u_m$. Since the container mechanisms work in a closed loop, we can assume that this variable domain is a closed set. The control is possible inside and at the border, that is $u_1(t)=u_1^*$.

At the stage of circuit synthesis under conditions of information scarcity, the equations of theoretical (unperturbed) motion are used to describe the kinematics of the elements of mechanical systems. However, already at the design, manufacturing and testing stages, there will be some deviations from the design conditions, i.e. the actual movements of the elements of the folding container will differ from the theoretical ones. To account for these deviations, it is customary to use perturbation equations, the structure of which includes a parameter that takes these deviations into account.

Let the kinematic scheme be found, and the equation of theoretical motion is drawn up. Hence, the function $u^*(t)=u_k^{(0)}(t)\ (k=1,\ m)$ is known. Solving equation (1) taking into account the value of this function and the constraints (3), (4) we obtain $x_i^*(t)\ (i=1,\ n)$. Then the equation that will describe the real motion of the elements of the projected system can be obtained by entering the perturbation (deviation) function

If $\delta_{xi}(t)\ (i=1,\ n)$ and $\delta_{uk}(t)\ \ (k=1,m)$ — the deviations of the real motion and control from the theoretical one, then the perturbed motion of the system is described by the functions:

$$x_i(t)=x_i^*(t)+\delta_{xi}(t)u_k(t)=u_k^*(t)+\delta_{uk}(t)\cdot(i=1,n;k=1,m) \tag{7}$$

According to the theory of adaptive control, the numerical values of deviations $\delta_{xi}(t)$ $(i=1,\ n)$ are unknown and are random small quantities. In this case, their range should not exceed a certain specified number, i.e., satisfy an inequality of the form:

$$\sum_{i=1}^{n} \delta_{xi}^{2}(t_0) \le \varepsilon^{2} \tag{8}$$

Next, for the perturbed motion of the system (5), we express the control efficiency as a function of variable states:

$$\gamma = \int_{t_0}^{t_1} \left[x_i(t) + u_k(t) \right] \cdot dt = \int_{t_0}^{t_1} \left\{ \left[x_i^*(t) + \delta x_i(t) \right] + \left[u_k^*(t) + \delta u_k(t) \right] \right\} \cdot dt \tag{9}$$

So, the solution to the problem can be reduced to minimizing the functional (5) in a given interval $(t_1,\ t_0)$ i.e.:

$$\gamma = \lim_{t_1 \to \max} \frac{1}{t_1 - t_0} \times \int_{t_0}^{t_1} \left\{ \left[x_i^*(t) + \delta x_i(t) \right] + \left[u_k^*(t) + \delta u_k(t) \right] \right\} \cdot dt \tag{10}$$

One of the approaches to solving the problems of analytical design (synthesis) of the controller is to determine the matrix ***c*** of numbers with the dimension $m \times n$ of the controller equation, which in the first approximation can be described by the equation in matrix form:

$$u = c \cdot x \tag{11}$$

where c — the matrix of numbers; x — the movement of the object.

The implementation of this approach makes it possible to ensure the stable movement of the control object in case of disturbed motion.

Let us consider the control and state parameters as functions of the control and state variables for the case when they do not depend on the initial conditions from some set (7), which have the following form:

$$x_i^*(t) + \delta x_i(t) = \phi_1 \cdot [(x_1 ... x_i), (\delta x_1 ... \delta x_i)] \tag{12}$$

$$u_k^*(t) + \delta u_k(t) = \phi_2 \cdot [(u_1 ... u_k), (\delta u_1 ... \delta u_k)] \tag{13}$$

Thus, the container mechanism control function includes parameters for which the constraints are known, but their current values are not known. However, the structure of adaptive systems implies the possibility of forming a function that contains a criterion for changing these parameters:

$$\beta(t) = \phi_3(\beta,\ u) \tag{14}$$

where $\beta(t)$ — the adapter, i.e. the system element implementing the adaptation mechanism.

So, the algorithm of the controller operation is described by equations (12), (13), and the algorithm of the adaptation process is described by equation (14) containing the adapter. In the considered version of the design of the folding container, the adapter with a given load F_n and speed V_n parameter that determines the control resource will be a gas spring, and the parameters of control and the state of the object, respectively, the load-speed characteristics of the leading link F_0, V_0 (lifting mechanism) and the driven kinematic circuits F_i, V_i.

$$\beta(t) = \phi_3(F_n, C_n) \quad u(t) = \phi_2(F_0, V_0) \quad x(t) = \phi_1(F_i, V_i) \tag{15}$$

Operational tests. To check the operability of the proposed design of the folding cargo container, the tests of the prototype mechanisms were carried out. The development of technical documentation, production and testing of the prototype was carried out in OOO IKTS "Mysl".

The test of the container mechanisms showed their operability, namely, the ability of such a structure to balance the own weights of the roof, side and end walls, including the sectional doors, during the folding and unfolding process, due to the use of lockable gas springs.

The use of gas springs as an adapter allows you to realize the effect of functional self-adaptability to the operating conditions of both the control parameters and the parameters of the object state. Moreover, the effect is quite well realized along the entire trajectory of the container elements without the use of external lifting mechanisms.

Conclusion. The proposed approach to improving the design of a collapsible container will allow us to more effectively solve the logistics problems of transportation in an urban environment by:

- improving the safety of people during preparatory operations;
- reduction of fuel costs by reducing the speed of transport;
- reduction of congestion on urban roads;
- reduction of the environmental burden.

For the practical implementation of the proposed design solution, the method of synthesis of the adaptive controller of the folding-unfolding process of the container mechanisms is presented in a general form.

In addition, as tests have shown, the use of gas lockable springs as connecting elements between the driving links and the driven kinematic chains ensured the normal functioning of the object without the use of external, not related directly mechanisms.

References

1. Korotkiy A. A., Galchenko G. A., Ivanov V. V. Informatsionno-kommunikatsionnaya logisticheskaya sistema dlya optimizatsii transportnykh marshrutov v urbanizirovannoy srede [Information and communication logistics system for optimizing transport routes in an urban environment]. Nauchno-tekhnicheskiy vestnik Bryanskogo gosudarstvennogo universiteta. 2018;4:60–63. (In Russ)

2. Petrov O. A., Evstratov E. M. et al. Skladnoy gruzovoy konteyner. Patent Russian Federation No. 2672998 S1, 2018. (In Russ)

3. Korotkiy A. A., Egelskaya E. V. Otsenka riska chelovecheskogo faktora v sisteme ‘personal – pod’emnye mekhanizmy – proizvodstvennaya sreda’ na predpriyatiyakh mashinostroeniya [Risk assessment of the human factor in ‘staff - hoists - production environment’ system at machine-building enterprises]. Vestnik of Don State Technical University. 2015;15(1):131–137. DOI: 10.12737/10396. (In Russ)

4. Kraynev A. F. Ideologiya konstruirovaniya [Design ideology]. Moscow: Mashinostroenie-1, 2003. 384 p. (In Russ)

5. Polovinkin A. I. Osnovy inzhenernogo tvorchestva [Fundamentals of engineering creativity]. Moscow: Mashinostroenie, 1988. 368 p. (In Russ)

6. Demyanov Al. An., Demyanov Al. Al., Frolov K. V. (ed) et al. Metod adaptivnogo sinteza friktsionnykh sistem [Method of adaptive synthesis of friction systems]. Mashinostroenie. Entsiklopediya. Moscow: Mashinostroenie. 2008:72–74. (In Russ)

7. Putov V. V., Lebedev V. V., Putov A. V. Adaptivnye sistemy upravleniya mnogostepennymi zhestkimi nelineynymi mekhanicheskimi ob’ektami, postroennye po ikh uproshchennym modelyam s mazhoriruyushchimi funktsiyami [Adaptive control systems multistage nonlinear rigid mechanical objects, built on their simplified models with majorizing functions]. Proceedings of Saint Petersburg Electrotechnical University. 2013;10:49–54. (In Russ)

8. Nesterov S. A. Adaptivnye sistemy upravleniya: konspekt lektsiy [Adaptive control systems: lecture notes]. Saint-Petersburg: Fakul'tet tekhnicheskoy kibernetiki SPbGPU, 2005. 90 p. (In Russ)

Submitted 22.03.2021
Scheduled in the issue 30.04.2021

Authors:

Anatoliy A. Korotkiy, Head, Department of Transport Systems Operation and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Dr. Sci. (Eng.), Professor, ORCID: https://orcid.org/0000-0001-9446-4911 , korot@novoch.ru

Aleksandr A. Demyanov, Professor, Department of Transport Systems Operation and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Dr. Sci. (Eng.), ORCID: https://orcid.org/0000-0001-7137-7540 , a11exxandr@yandex.ru

Aleksey A. Demyanov, Associate Professor, Department of Transport Systems Operation and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Cand. Sci. (Eng.), ORCID: https://orcid.org/0000-0002-2308-6295 , alexys61@yandex.ru

Contribution of the authors:

A. A. Korotkiy — the main idea of the project, justification of the influencing factors, development of the general research program; Aleksandr A. Demyanov — development of questions of the theoretical part; Aleksey A. Demyanov — analysis of the results of the study, formulation of directions for improving the design, design of the text of the article.

UDC 658.13 https://doi.org/10.23947/2541-9129-2021-2-33-42

Use of containers-transformers and platooning in megacities — a way to environmental ecology improvement

A. A. Korotkiy, N. N. Nikolaev, G. A. Galchenko, I. V. Yurgin

Don State Technical University (Rostov-on-Don, Russian Federation)

Introduction. Growth of cities and, accordingly, highways influences the quality of air, soil and water resources considerably. Dangerous emissions from cars in the form of sulfur compounds, nitrogen and carbon oxides, acid rain negatively affect people's health every day. In this regard, great importance is attracted to the transportation process optimization. One of the main problems of the transport and logistics services market is the transportation of empty cargo containers as returnable containers, which leads to unjustified fuel costs, labor resources, depreciation of vehicles, road congestion, and has a huge impact on the environment. Within the framework of the National Technology Initiative, approved by the Presidium of the Presidential Council for Economic Modernization and Innovative Development of Russia in 2018, in terms of the priority market direction — "Transport and logistics services" — a solution to the environmental problem is proposed through the use of smart automated containers-transformers equipped with an information system for remote administration, scenario management and mobile applications.

Problem Statement. It is necessary to develop a project that will eliminate technological barriers and optimize transport and logistics services. The implementation of this project should reduce the time of cargo delivery: loading/unloading, empty runs, breaks in work, optimize the delivery path, using newly created mobile applications based on modern high-level programming languages.

Theoretical Part. The SmartBoxCity container-transformer is a part of an information system that includes server and client software. Data exchange with the server is based on the information from the database on the states of the elements of the SmartBoxCity system. "Yandex. Routing" calculates routes and optimizes the operation of vehicles. The movement of motor vehicles is on "closed" optimal routes. Platooning in urban environments takes into account empty and loaded containers in real time, taking into account the dynamics of data.

Conclusion. A practical solution to optimizing the activities of transport companies is proposed, which reduces the time for loading/unloading up to 30%, the share of empty runs up to 25%, and logistics costs for transporting empty containers up to 75%. The organization of platooning creates conditions for optimizing urban mobility, saving fuel, and improving the environmental situation.

Keywords: container, platooning, mobile application, ecology.

For citation: Korotkiy A. A., Nikolaev N. N., Galchenko G. A., Yurgin I. V. Use of containers-transformers and platooning in megacities — a way to environmental ecology improvement; Safety of Technogenic and Natural Systems. 2021;2:33–42. https://doi.org/10.23947/2541-9129-2021-2-33-42

Introduction. Violation of the ecological balance of man and nature, modern environmental negative trends require a careful, scientifically based approach to many problems and, in particular, to the organization of the transport process. Many scientists are trying to solve the problems of improving the organization of traffic to reduce emissions of car exhaust gases into the atmosphere [1, 2]. One of the main problems of the transport and logistics services market is the transportation of empty cargo containers as returnable containers, which leads to unjustified fuel costs, labor resources, depreciation of vehicles, road congestion, and has a huge impact on the environment. In this paper, within the framework of the project that corresponds to the goals and objectives of the "Autonet" Roadmap of the National

Technology Initiative, approved by the Presidium of the Presidential Council for Economic Modernization and Innovative Development of Russia in 2018 (hereinafter referred to as the "Autonet" DC NTI), in terms of the priority market direction — "Transport and logistics services" — a solution to the environmental problem is proposed by using smart automated containers-transformers equipped with an information system for remote administration, scenario management and a mobile application.

Problem Statement. It is necessary to present a project developed in theoretical and technical terms that allows optimizing transport and logistics services and eliminating technological barriers, namely:

— reducing the share of empty vehicle runs by 3 or more times;

— reducing at least by 2 times the interruptions in work related to the human factor;

— reducing travel time by 50% thanks to automatic route optimization, taking into account the traffic load on the roads;

— organizing the mass use of the caravan movement of empty and loaded with folded containers-transformers vehicles;

— developing the software based on the GNU Linux OS using the high-level Python programming language.

Theoretical Part. The SmartBoxCity containers-transformers [3] create conditions for organizing platooning for cargo delivery when providing transport and logistics services to the vehicle [4-6].

The project is based on the end-to-end NTI technology — "Wireless Communication and Internet of Things Technologies", since the SmartBoxCity container-transformer is a part of an information system that includes the server and the client software.

The container is equipped with various sensors for measuring weight, temperature, humidity, opening. It is equipped with a built-in computer and a video monitoring system. Data exchange with the server is carried out by files that are formed on the basis of information from the database (DB) about the states of the elements of the SmartBoxCity system. Using the database, the Yandex.Routing system calculates routes and optimizes the operation of vehicles, and then generates a response file in accordance with the information received.

Server software extracts the information from the file, puts it in the database, and transmits it to the mobile application. The vehicle moves on "closed" optimal routes with constantly adjusted parameters. Taking into account the principles of platooning in an urban environment, there is a dynamic change in the data transmitted from the Yandex.Routing service: the position of the car, its tags, and the space available for the containers transportation. At the end of each stage of transportation, the data is updated in accordance with the new state of the vehicle and is again transmitted to the Yandex.Routing service.

When platooning, the effect of a "mobile warehouse" of small capacity is used — stacked containers and multiple use of the vehicle alternately as: unloaded (empty); container with cargo; moved folded containers (mobile warehouse of small capacity) or simultaneously performing the two functions listed above. The described platooning allows you to repeatedly use empty containers on orders, without placing them each time in a stationary warehouse.

Introduction of logistics to the "brain" system based on the program Yandex.Routing allowed us to solve this problem without visual control. There is no need for a lead driver. A caravan of cars is reduced to a caravan of containers that are temporarily attached to cars, transported in a platooning along the shortest routes formed by the system, and detached at the destinations.

In a folded position, the SmartBoxCity container-transformer is a compact parallelepiped, the storage or transportation of which requires a minimum volume [7-10].

When an application is received, a vehicle with containers can change the route by moving to the specified address or returning to the main route. The proposed type of platooning using the SmartBoxCity container allows you to use empty containers on orders, without placing them each time in a stationary warehouse.

Figure 1 shows the proposed scheme of platooning.

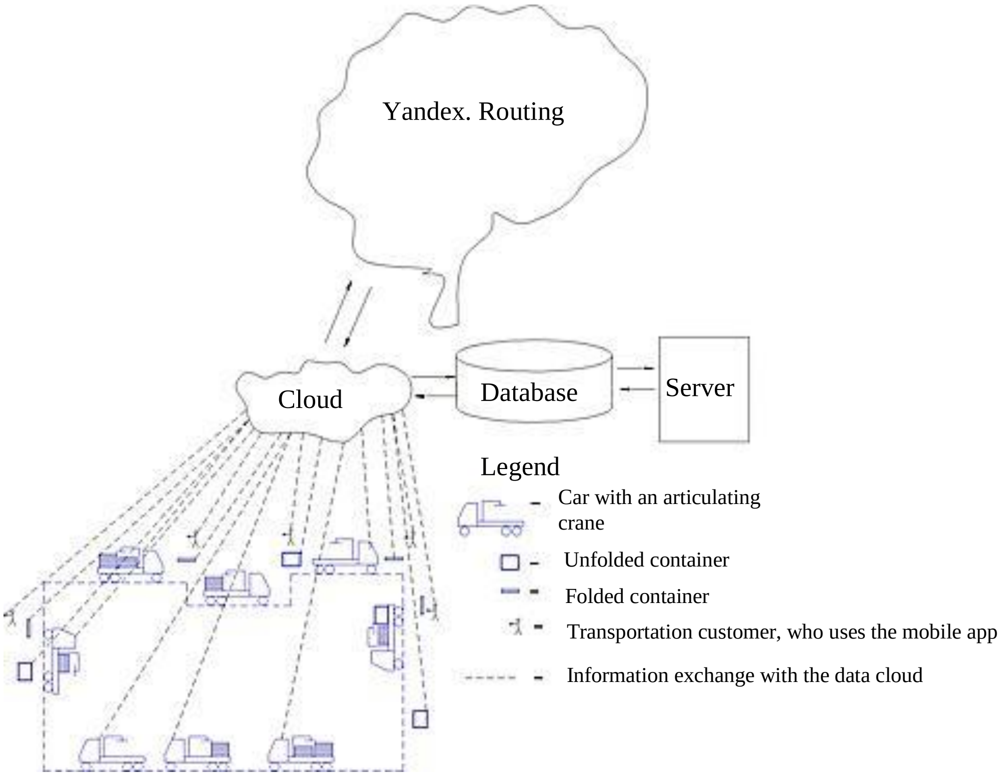

Yandex. Routing
Cloud
Database
Server
Legend
Car with an articulating crane
Unfolded container
Folded container
Transportation customer, who uses the mobile app
Information exchange with the data cloud

Fig. 1. The proposed scheme of platooning

Self-loading trucks carrying folded containers and empty self-loading trucks are distributed in a certain way in the serviced territory, depending on the forecasted traffic volumes. If there are no orders, the cars are either on-site or independently move to areas of high demand.

In the city conditions, the platooning is understood as a form of organization of vehicles movement, in which several cars take part in the delivery of cargo at once, alternately performing their functions. These vehicles are connected by modern means of communication. To improve the performance of the system and adjust routes, interaction is carried out in real time.

The SmartBoxCity container-transformer management software is designed to run on the RPLC-1000 programmable controller. Figure 2 shows the layout diagram of the controller. The controller has the following features:

- monitoring the status of discrete input signals;
- control of discrete (transistor) outputs;
- receiving and transmitting data via RS-485, RS-232, Ethernet interfaces;
- support for third-party hardware via modbus RTU, TCP, UDP;
- connect monitors to display information via the built-in HDM port;
- logging and storing logs on remote servers;
- direct connection of the controller to the Internet, connection to OpenVPN to create a private distributed network;
- support for ccTalk and SSP protocols. The MDB protocol is supported via an optional signal conversion device.

It is possible to connect external analog and digital I/O modules to the controller via Ethernet, RS-485 port or a special, built-in expansion bus. Table 1 shows the controller interfaces.

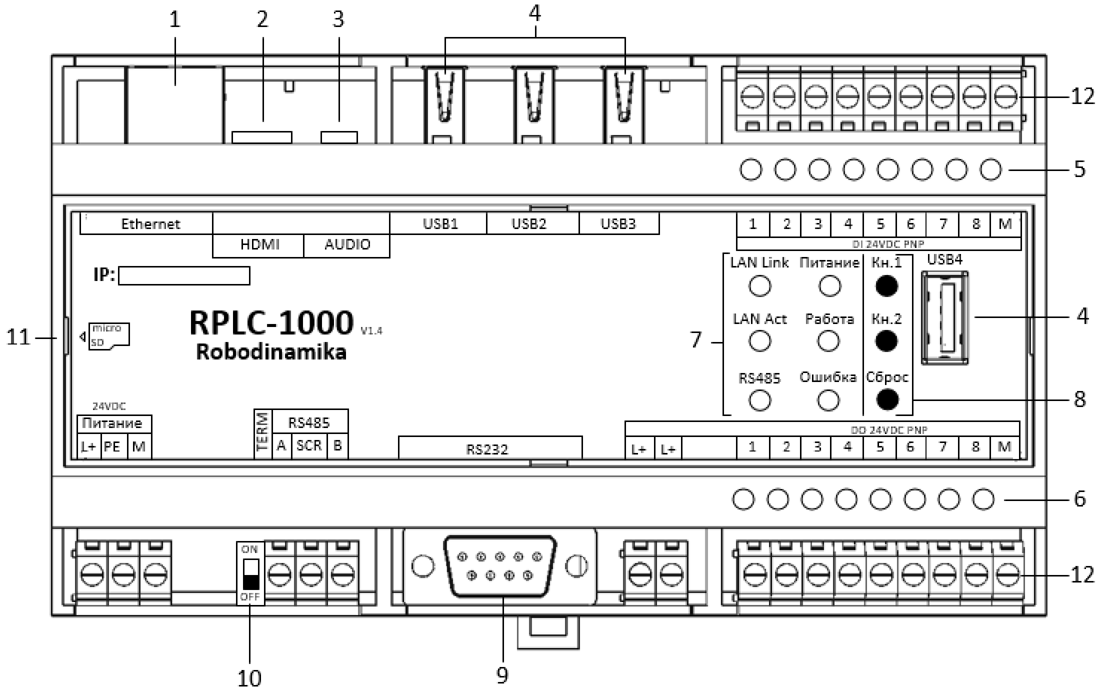


Fig. 2. Layout diagram of the RPLC-1000 controller

Table 1

Description of the controller interfaces

No.	Name	Description
1	Ethernet (RJ-45 connector)	The 100 Base-T Ethernet port is designed for connecting a PLC to a local network
2	HDMI (HDMI rev 1.3 & 1.4 connector)	Interface for transmitting digital video data and multi-channel digital audio signals
3	Audio (Audio jack 3.5 mm connector) *Option	Analog audio jack
4	USB1-USB4 (USB Type-A connector)	Ports for USB devices
5	LED input status indicators	Controller inputs status indication
6	LED output status indicators	Controller outputs status indication
7	LED PLC status indicators	Status indication
8	Built-in buttons	Reset button and two non-locking programmable buttons
9	RS-232 (DB9-M connector)	Serial interface for connecting devices
10	Switch of the terminator (matching resistor)	Switching on the matching resistor with a nominal value of 120 ohms
11	MicroSD slot	MicroSD card slot
12	Terminal blocks	For connecting the power supply of the device, digital inputs, actuators, RS-485 interface

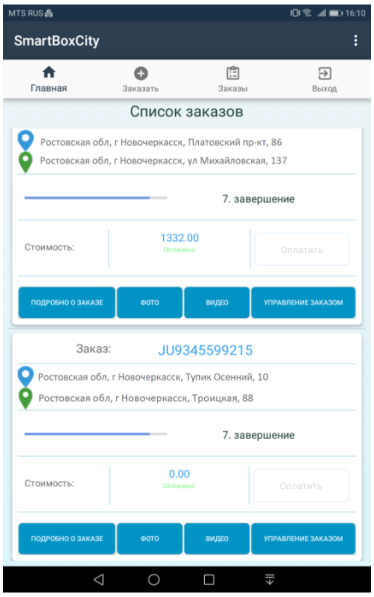
Field tests performance. Full-scale tests of the SmartBoxCity prototype on transport were carried out using a sequential approach — from the "application" stage to the "completion" stage.

At the "application" stage, an order was made — a stand for simulating traffic for testing and calibration — according to the following parameters**:**

— departure point — Novocherkassk, Osenniy Tupik, 10 (Fig. 3);

— destination — Novocherkassk, Troitskaya str., 88 (Fig. 3);

— cargo length, width, height, weight and the number of pieces: 550×410×100, 48 kg, 6 pieces and 230×180×105, 10 kg, 2 pieces, total 308 kg (load on the floor of the container 3kN);



Список заказов

Ростовская обл, г Новочеркасск, Платовский пр-кт, 86
Ростовская обл, г Новочеркасск, ул Михайловская, 137

7. завершение

Стоимость: 1332.00 Оплачено

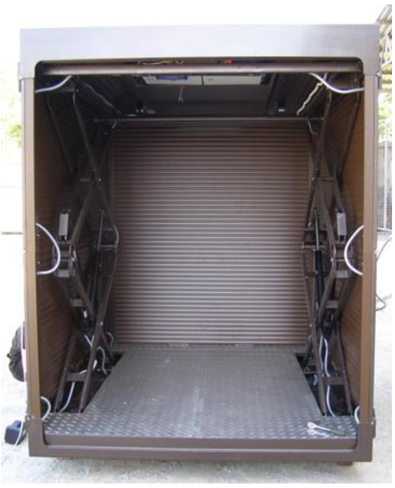
Заказ: JU9345599215

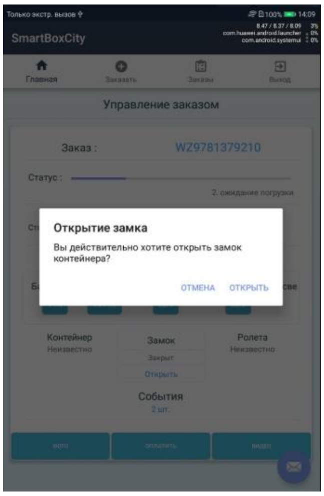
Ростовская обл, г Новочеркасск, Тупик Осенний, 10
Ростовская обл, г Новочеркасск, Троицкая, 88

7. завершение

Стоимость: 0.00 Оплачено

Fig. 3. Departure point





Управление заказом

Заказ : WZ9781379210

Статус : 2. ожидание погрузки

Открытие замка

Вы действительно хотите открыть замок контейнера?

Контейнер Неизвестно

Замок Закрыт

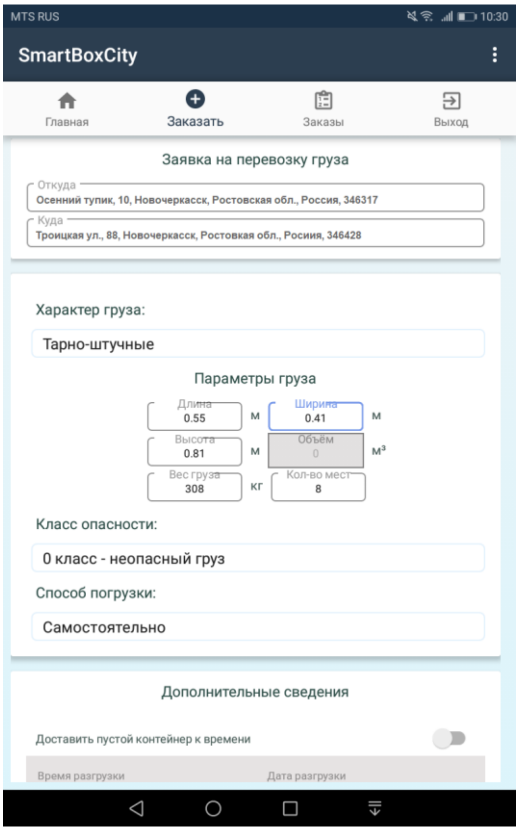
Ролета Неизвестно

События 2 шт.

Fig. 4. Loading stage

— "Waiting for cargo" stage — the container is unloaded on the site and the container is assembled.

— "Loading" stage (Fig. 4-6) — the door is opened (roller door). The cargo is placed in the container; the container door is closed; the readiness of the container for transportation is confirmed.



Заявка на перевозку груза

Откуда: Осенний тупик, 10, Новочеркасск, Ростовская обл., Россия, 346317

Куда: Троицкая ул., 88, Новочеркасск, Ростовкая обл., Росиия, 346428

Характер груза: Тарно-штучные

Параметры груза

Длина 0.55 м
Ширина 0.41 м
Высота 0.81 м
Объём 0 м³
Вес груза 308 кг
Кол-во мест 8

Класс опасности: 0 класс - неопасный груз

Способ погрузки: Самостоятельно

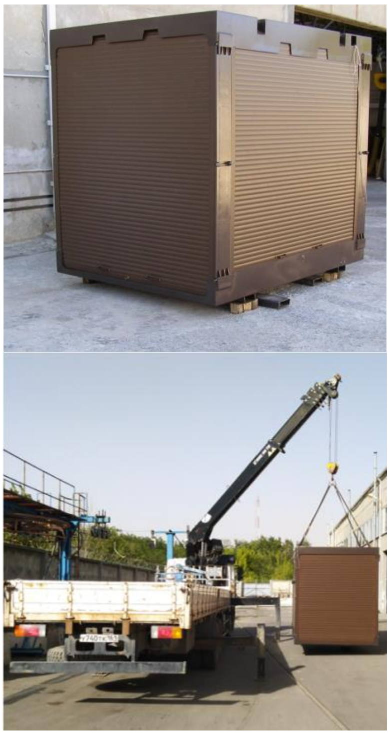
Дополнительные сведения

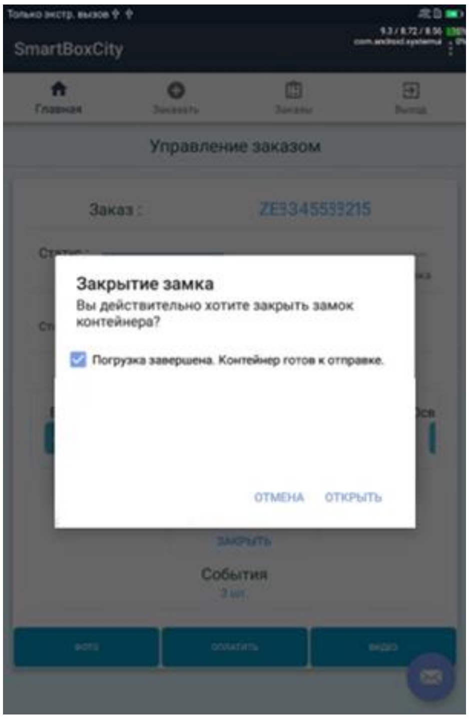
Доставить пустой контейнер к времени

Время разгрузки

Дата разгрузки

Fig. 5. Loading stage





Управление заказом

Заказ : ZE9345599215

Закрытие замка

Вы действительно хотите закрыть замок контейнера?

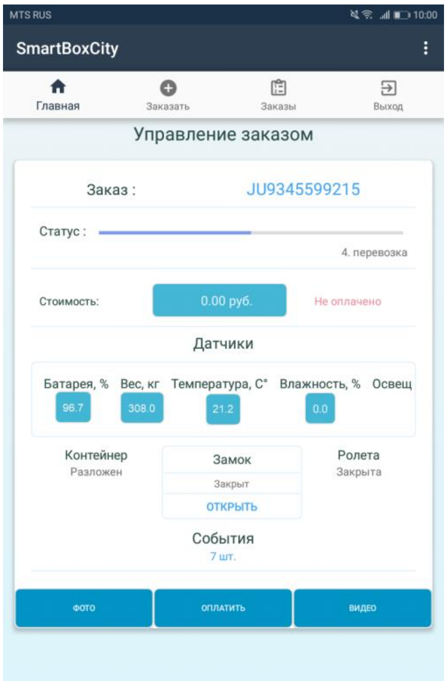
☑ Погрузка завершена. Контейнер готов к отправке.

События

Fig. 6. Loading stage

— "Transportation" stage — all cargo parameters are checked; the container is placed on the vehicle; the container is delivered to the destination (Fig. 7-8);

— "Waiting for unloading" stage — confirmation of payment for the container transportation.



MTS RUS 10:00

SmartBoxCity

Управление заказом

Заказ : JU9345599215

Статус : 4. перевозка

Стоимость: 0.00 руб. Не оплачено

Датчики

Батарея, %	Вес, кг	Температура, С°	Влажность, %	Освещ
96.7	308.0	21.2	0.0	

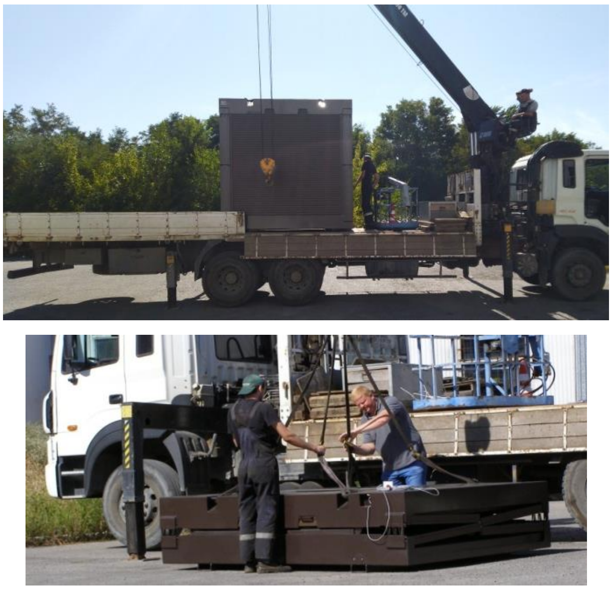
Контейнер
Разложен

Замок
Закрыт
ОТКРЫТЬ

Ролета
Закрыта

События
7 шт.

Fig. 7. Transportation stage



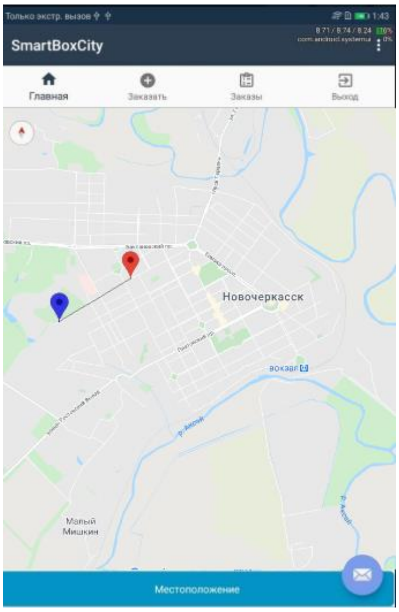
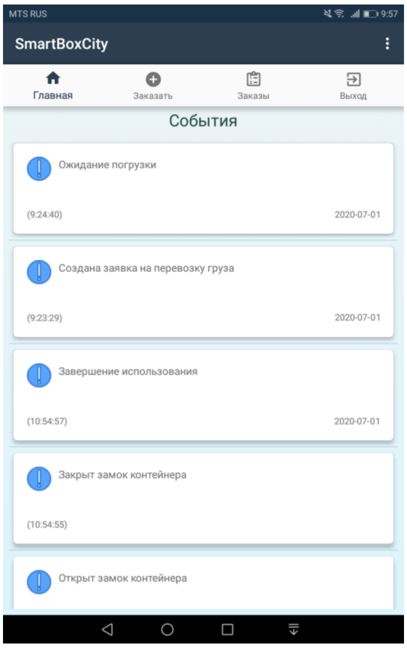


Fig. 8. Transportation stage

— "Unloading" stage — the container is removed from the vehicle. All cargo parameters are checked, the door is opened; the cargo is removed from the container; the unloading is confirmed and the container door is closed.

— "End of use" stage — the container is stored in the transport state; the container is placed on the vehicle; the button is pressed to switch the container to the "free to order" mode; the container is returned to the stand for simulation of movement, testing and calibration.



События

Ожидание погрузки
(9:24:40) 2020-07-01

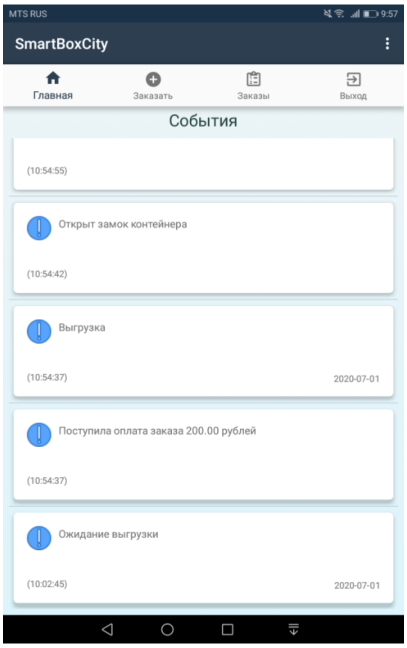
Создана заявка на перевозку груза
(9:23:29) 2020-07-01

Завершение использования
(10:54:57) 2020-07-01

Закрыт замок контейнера
(10:54:55)

Открыт замок контейнера

Fig. 9. Control over the parameters and functionality via the app



События

(10:54:55)

Открыт замок контейнера
(10:54:42)

Выгрузка
(10:54:37) 2020-07-01

Поступила оплата заказа 200.00 рублей
(10:54:37)

Ожидание выгрузки
(10:02:45) 2020-07-01

Fig. 10. Control over the parameters and functionality via the app

All the stages are performed using the SmartBoxCity mobile app and by pressing the appropriate buttons. The prototype has passed full-scale tests on transport and is suitable for further operation.

Conclusion. Simulation of the transportation process using simulators showed a decrease in the share of empty runs of cargo vehicles by more than 3 times due to the use of platooning and a vehicle with a body for two loading places.

The interruptions in work related to the human factor are reduced by more than 2 times, due to the combination of the profession of slinger, driver and freight forwarder, remote online payment and lack of waiting. Travel time is reduced by 50 % thanks to route optimization. Logistics of the platooning of the vehicle with a body for two loading places is organized in cooperation with the Yandex.Routing program.

The containers are equipped with the information system for remote administration, scenario management, and mobile applications. The use of platooning in an urbanized environment is a system-forming interaction of all the components of the technological process of cargo delivery in urban conditions.

The approach based on the Internet of Things technology provides a high level of technological reliability of the logistics chain with a low level of costs. The method of implementing platooning is aimed at improving the efficiency of three main aspects of road traffic: environmental protection, safety and reducing traffic congestion on routes, providing more comfortable working conditions for drivers. The movement of vehicles is on "closed" optimal routes, taking into account the parameters that are constantly adjusted depending on the statistics of incoming orders and traffic congestion.

References

1. Kuren S. G., Galchenko G. A. Modelirovanie transportnykh potokov: monografiya [Modeling of transport flows: monograph]. Moscow: Pero, 2020. 168 p. (In Russ.)

2. Kuren S. G., Popov S. I., Dontsov N. S., Zubareva E. G. Evolyutsiya khimicheskogo sostava vybrosov zagryaznyayushchikh veshchestv v atmosferu v gorode-millionnike [Evolution of the chemical composition of emissions of pollutants into the atmosphere in the city]. Engineering journal of Don. 2018;2:133. (In Russ.)

3. Petrov O. A. et al. Skladnoy gruzovoy konteyner [Folding cargo container]. Patent 2672998 Russian Federation: B65D 88/52 / no. 2017136697; 2017. (In Russ.)

4. Korotky A. A., Popov S. I., Galchenko G. A., Marchenko Yu. V., Drozdov D. S. The use of SmartBox container for agrobusiness logistic processes optimization. XIII International Scientific and Practical Conference «State and Prospects for the Development of Agribusiness – INTERAGROMASH 2020»: E3S Web of Conferences, 2020;175:13019, Rostov-on-Don, Russia, 2020, 26-28.

5. Zyryanov V. V. Rukovodstvo po modelirovaniyu dorozhnogo dvizheniya: uchebnoe posobie [Road Traffic Simulation Guide: A Tutorial]. Rostov-on-Don: Rostov State University of Civil Engineering, 2015. 61 p. (In Russ.)

6. Marchenko E. V., Popov S. I., Marchenko Yu. V. et al. Tekhnicheskie izmereniya na transporte: ucheb. posobie [Technical measurements in transport: textbook]. Rostov-on-Don: DSTU Publishing center, 2017. 81 p. (In Russ.)

7. Popov S. I., Runkevich Yu. P., Marchenko Yu. V. et al. Tekhnicheskie sredstva diagnostirovaniya transportnykh mashin: uch. posobie [Technical means of diagnosing transport vehicles: textbook]. Rostov-on-Don: DSTU Publishing center, 2016. 199 p. (In Russ.)

8. Kushchenko S. V. Povyshenie effektivnosti organizatsii dvizheniya na osnove modelirovaniya transportnykh potokov: dis. k-ta tekhn. nauk [Improving the efficiency of traffic management based on traffic flow modeling: author’s thesis]. Kursk, 2012. 134 p. (In Russ.)

9. Fialkin V. V., Kolesnikov E. I. Modelirovanie transportnogo sprosa v g. Rostove-na-Donu dlya izucheniya nagruzki na dorozhnuyu set' [Traffic demand’s simulation in Rostov-on-Don to study the road network load]. Young researcher of the Don. 2020;5(26):64–70. (In Russ.)

10. Yakimov M. R. Transportnoe planirovanie: sozdanie transportnykh modeley gorodov: monogr. [Transport planning: creating transport models of cities: monogr.]. Moscow: Logos, 2013. 188 p. (In Russ.)

Submitted 04.03.2021

Scheduled in the issue 14.04.2021

Authors:

Korotkiy, Anatoliy A., Head, Department of Operation of Transport Systems and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Dr. Sci., Professor, ORCID: https://orcid.org/0000-0001-9446-4911 , korot@novoch.ru

Galchenko, Galina A., Associate Professor, Department of Operation of Transport Systems and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Cand. Sci., Senior Researcher, ORCID: https://orcid.org/0000-0001-5966-0423 , ggalchenko@inbox.ru

Nikolaev, Nikolay N., Associate Professor, Department of Operation of Transport Systems and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Cand. Sci., Associate Professor, ORCID: https://orcid.org/0000-0003-2087-0233 , nnneks@yandex.ru

Yurgin, Ivan V., Post-graduate student, Department of Transportation and Traffic Management, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), ORCID: https://orcid.org/0000-0001-6828-8512 , cent96v@yandex.ru

Contribution of the authors:

A. A. Korotkiy — formulation of the main concept, goals and objectives of the study; N. N. Nikolaev — development of the process flow diagram; G. A. Galchenko — analysis of the research results, revision of the text, correction of conclusions; I. V. Yurgin — description of the principles of platooning functioning.

UDC 614.8.84 https://doi.org/10.23947/2541-9129-2021-2-43-49

Analysis and assessment of the safety level of port facilities using the example of a sulfur storage warehouse

L. E. Pustovaya, V. A. Chebysheva

Don State Technical University (Rostov-on-Don, Russian Federation)

Introduction. The article deals with the problems of analysis and assessment of the safety level of hazardous production facilities of port facilities that have a negative impact on both the environment and the personnel working at the facility. Objects of this kind are referred to the first class of hazard; therefore, they require a comprehensive assessment of their resistance to emergencies in terms of the likelihood of their occurrence in specific industrial conditions.

Problem Statement. The objective of this study is a comprehensive analysis of the safety level of the most vulnerable areas of the technological process of port activities.

Theoretical Part. The results of a scheduled inspection of the AO “Ust-Donetsk Port” conducted by the Federal Service for Supervision of Natural Resources were used as basic information.

Conclusion. Based on the calculation results, it was found that the probability of an emergency for the most dangerous scenario is 2.4×10-8 and corresponds to the acceptable risk zone.

Keywords: emergency, production factors analysis, safety, event tree, damage, calculation of the emergency probability.

For citation: Pustovaya L. E., Chebysheva V. A. Analysis and assessment of the safety level of port facilities using the example of a sulfur storage warehouse; Safety of Technogenic and Natural Systems. 2021;2:43–49. https://doi.org/10.23947/2541-9129-2021-2-43-49

Introduction. At present, there is a significant progress in the field of port activities. The increase in the volume of cargo transportation and transshipment increases the need to improve the environmental safety of sea and river ports. The problem of the negative impact of cargo handling and storage operations in ports on the environment and industrial safety has not been fully solved to date. The most dangerous factor is dusting and flue dust during storage in open warehouses and transshipment operations of bulk cargo [1, 2]. In addition, dust from combustible materials can create explosive aerosols under certain conditions. It is also known that when unloading and loading both bulk and loose cargo, ship-borne cargo volume losses are often possible, which can have a detrimental effect on the atmospheric air, soil and water body [3].

Ust-Donetsk Port is the largest river port in the south of Russia, which is located on the right bank of the Sukhoy Donets Channel. The total length of the waterfront is more than 1,100 m. The port is assigned a high risk category and a second hazard class. The main production cycles are stevedore operations; open and indoor warehouse storage of cargo; complex logistics; packaging of cargo in big bags, as well as fleet maintenance, which includes the processes of production, repair work and provision of onshore power supply. Cargo transshipment is carried out on floating vehicles board using a crane with a grab, a floating crane with a grab and a motor ship, using the "car-ship" and/or "warehouse-ship" method. The structure is characterized by a predominance of bulk, general and chemical cargo. Most of them are dangerous according to GOST 19 433-88, for example, sulfur, the volume of transshipment of which reaches 1.5 million tons per year. Based on the above, for the organization of storage and transshipment of goods, including those classified as dangerous, the port must be provided with an environmental infrastructure and meet the requirements of industrial safety. In order to recognize the probable danger, it is necessary to determine which key elements, technical systems or processes in the technological scheme of the transshipment significantly need to be analyzed in terms of minimizing the environmental risk of accidents, including the extreme weather conditions [4].

This study is devoted to determining the probability of an emergency in the most dangerous scenario.

Problem Statement. To solve this problem, it is necessary to analyze the technological process in the most dangerous area associated with the acceptance, storage and reloading of a fire-explosive substance — sulfur. The determination of the set of parameters of this type of cargo will allow us to assess the level of industrial safety and the probability of an emergency in the most dangerous scenario.

Theoretical Part. To perform calculations, it is necessary to establish the ecological and toxicological parameters of sulfur dust and the features of its behavior in the environment. Industrial gas sulfur (block, granulated) is a combustible solid crystalline substance that ignites from sparks and open flames. The maximum permissible concentration of sulfur in the working area is 6 mg/m^3, the maximum one-time concentration is 0.03 mg/m^3, and the average daily concentration is 0.005 mg/m^3. According to the degree of influence on the human body, sulfur belongs to the fourth hazard class according to GOST 12.1.005–88. The prolonged inhalation exposure to sulfur in concentrations exceeding the MPC in the air of the working area is likely to cause the development of chronic poisoning, characterized by disorders of the nervous system, gastrointestinal tract, and lung function disorders [5]. This dangerous factor is leveled mainly by the use of PPE.

No less important when assessing the level of safety of a sulfur warehouse is its fire and explosion hazard [6, 7], which determines the need to organize special industrial safety measures in the technology of the port transshipment process [8]. For the scientific development of such measures, it is necessary to assess the risk of an emergency at this facility [9-13].

At the stage of hazard identification at a hazardous production facility, it is necessary to identify the key sources of origin of probable incidents and accidents at a hazardous production facility, as well as general-type scenarios for the development of an accident at the considered hazardous production facility in accordance with Rostechnadzor Order No. 144 of 11.04.2016 On the Approval of the Safety Manual "Methodological bases for conducting hazard analysis and risk assessment of accidents at hazardous production facilities".

Table 1 presents a list of determining factors and possible causes that serve as a tool for the occurrence and development of accidents in the implementation of technological operations with sulfur at ZAO Ust-Donetsk Port.

Table 1

List of determining factors and possible causes that serve as a tool for the occurrence and development of accidents when handling with sulfur

Name of the technological block	Factors contributing to the occurrence and development of emergencies	Possible causes of emergencies
Platform for loading/unloading of sulfur from the railway car	1. A large amount of sulfur unloaded from the railway car creates a risk of formation of an increased amount of explosive sulfur dust. 2. When a large amount of explosive sulfur dust is formed, there may be a risk of explosion, the ignition of sulfur, the involvement of additional masses of fire-hazardous substances in the fire center, the chain development of the accident.	1. Errors of personnel in the conduct of technological operations (loading, unloading). 2. Unauthorized third-party interference. 3. External influence of natural and man-made nature. 4. Terrorist manifestations.
Platform for loading/unloading	1. A large amount of sulfur discharged from the railway car creates a risk of formation of	1. Errors of personnel in the conduct of the technological process (loading,

Name of the technological block	Factors contributing to the occurrence and development of emergencies	Possible causes of emergencies
sulfur from the car to the ship	an increased amount of explosive sulfur dust. 2. When a large amount of explosive sulfur dust is formed, there may be a risk of explosion, the ignition of sulfur, the involvement of additional masses of fire-hazardous substances in the fire center, the chain development of the accident.	unloading). 2. Unauthorized third-party interference. 3. External influence of natural and man-made nature. 4. Terrorist manifestations.
Sulfur storage warehouse	1. A large amount of sulfur stored in the warehouse creates a fire hazard.	1. Errors of personnel during the technological process (loading/unloading), repair and maintenance work. 2. Unauthorized third-party interference. 3. External influence of natural and man-made nature. 4. Terrorist manifestations.

Thus, among the causes of danger during the transshipping process, it is possible to specify the reloaded cargo, reloading equipment, technological process, human factor and meteorological conditions. We would also like to point out that errors in the management of the technological process of loading/unloading at the production facility can be not only the cause of the occurrence and development of emergencies, but also the cause of pollution of environmental components: atmospheric air, soil, the operated water body and lead to environmental damage.

Assessment of the risk of emergencies. The assessment of the probability of implementing the scenario of an accident at a sulfur storage warehouse was carried out on the basis of generalized average statistical data on the failure rates (depressurization) of production equipment, taking into account the number of units of equipment in operation, using the "event tree" analysis method according to RD 03-357-00 "Methodological recommendations for drawing up a declaration of industrial safety of a hazardous production facility" (Fig. 1). The probability of an emergency scenario is calculated by sequentially multiplying the frequency of the initial event by the relative probability of the intermediate stages of the accident development to the final event.

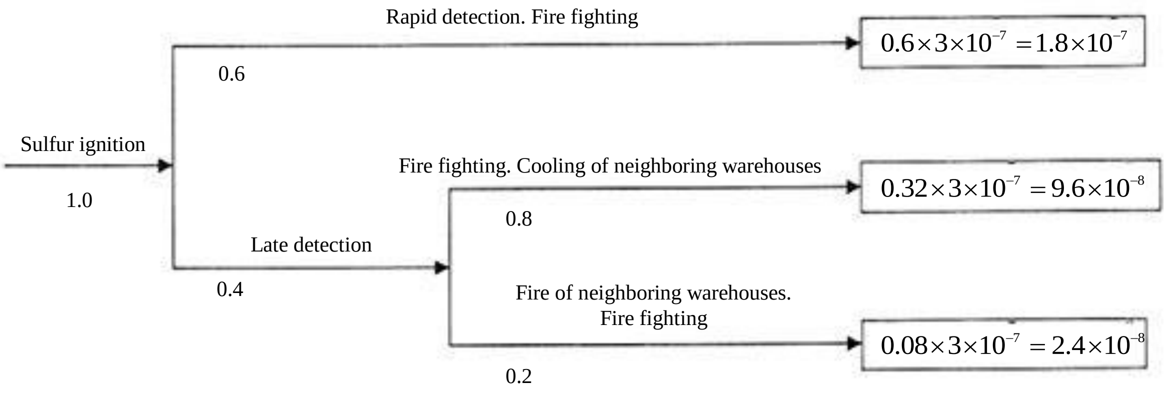

Rapid detection. Fire fighting
$0.6\times3\times10^{-7}=1.8\times10^{-7}$
0.6
Sulfur ignition
1.0
Fire fighting. Cooling of neighboring warehouses
$0.32\times3\times10^{-7}=9.6\times10^{-8}$
0.8
Late detection
0.4
Fire of neighboring warehouses. Fire fighting
$0.08\times3\times10^{-7}=2.4\times10^{-8}$
0.2

Fig. 1. "Event tree" of possible development of emergencies in case of an accident involving sulfur

Table 2 shows the results of the assessment of the probability of the accident scenario at the sulfur storage warehouse.

Table 2

Value of the frequency that triggers the event

Type of equipment failure	Probability of failure (incident)	Probability of an emergency scenario
Fire probability	3×10^{-7}	2.4×10^{-8}

An assessment of the risk of accidents when handling sulfur at AO Ust-Donetsk Port should be carried out for the most dangerous emergency scenarios, one of which is: the presence of an external heat source in the sulfur storage warehouse — fire — damage to the operating crew.

According to GOST R 12.3.047-2012 "Fire safety of technological processes" in the event of an accident at a production facility, the damaging factor is the dangerous thermal impact of a fire.

The most dangerous scenario of an accident (scenario no. 1) in a sulfur storage warehouse is: ignition of sulfur from an open fire source — late detection of a fire — ignition of adjacent warehouses, extinguishing of adjacent warehouses. The probability of scenario no. 1 in a sulfur storage warehouse is 2.4×10^{-8} year^{-1}.

The most likely scenario of an accident (scenario no. 2) is: the ignition of sulfur from an open fire source — rapid detection of ignition, fire extinguishing. The probability of scenario no. 2 in a sulfur storage warehouse is 1.8×10^{-7} year^{-1}.

The determination of hazard indicators of the object is made for the assumed variant of the implementation of an emergency that develops according to the most unfavorable scenario. It should be noted that, despite the scientific validity of qualitative and quantitative assessments of the risk of emergencies, they are probabilistic in their content and in the real case may not fully correspond to reality, since the methodology considers the generalized version in a simplified form. According to the "Method for determining the design value of the fire risk at production facilities" approved by Order of the Ministry of emergency situations of the Russian Federation No. 404 of 10.07.2009, the value of a potential fire risk P(a) (year^{-1}) at a certain point (a) at the premises of the production facility as well as on adjacent to the object area shall be determined using expression (1):

$$P(a) = \sum_{j=1}^{J} Q_{dj}\,(a) Q_j, \tag{1}$$

where J is the number of scenarios for the development of fire-hazardous situations (fires) (branches of the logical tree of events; Qdj (a) is the conditional probability of human injury at a certain point on the territory (a) as a result of the implementation of the j-th scenario for the development of fire-hazardous situations that corresponds to a certain event that initiates an accident; Qj is the frequency of the implementation of the j-th scenario for the development of fire-hazardous situations during the year, year-1

The value of the individual risk Rm for the employee m of the object on the territory of the object is determined by formula (2):

$$R_m = \sum_{i=1}^{I} q_{im} P(i), \tag{2}$$

where P(i) — the value of the potential risk in the i-th area of the object's territory, year^{-1}; q_{im} — the probability of the presence of employee m in the i-th area of the object's territory.

Possible total damage in the event of an accident at a hazardous production facility is determined by direct losses, the costs of localization and elimination of the consequences of the accident, socio-economic losses as a result of death and injuries of people and environmental damage according to RD 03-496-02 "Methodological recommendations for assessing damage from an accident at hazardous production facilities" (Fig. 2). As a result of an accident — a fire in a storage warehouse — the buildings and structures of the warehouse will be damaged, there will be a loss of sulfur, which will cause damage to the atmospheric air as a component of the environment. There may also be material losses associated with injuries to people. The results of the calculations are summarized in Table 3.

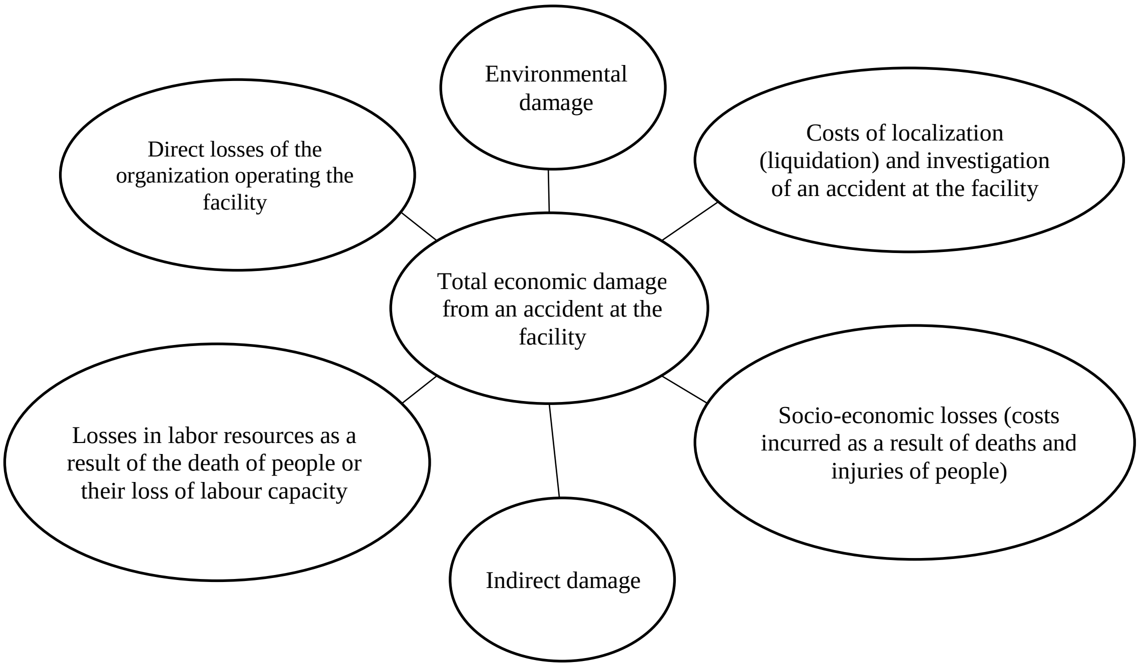

Environmental damage
Direct losses of the organization operating the facility
Costs of localization (liquidation) and investigation of an accident at the facility
Total economic damage from an accident at the facility
Losses in labor resources as a result of the death of people or their loss of labour capacity
Socio-economic losses (costs incurred as a result of deaths and injuries of people)
Indirect damage

Fig. 2. Scheme for calculating the amount of possible total damage in case of an accident at a hazardous production facility

Table 3

Results of calculating the risk of fire in sulfur storage warehouses

Place of accident occurrence	Probability of failure (incident) year^{-1}	Probability of an accident, year^{-1}	Potential fire risk, year^{-1}	Individual risk of an employee in a sulfur warehouse, year^{-1}	Estimated amount of damage, thousand rubles
Sulfur storage warehouse	3×10^{7}	2.4×10^{-8}	9×10^{7}	2.7×10^{-7}	3100

According to the results of calculations, the probability of an emergency for the most dangerous scenario is 2.4×10-8 year^{-1}, the value of the potential fire risk in the sulfur storage warehouse is 9×10-7 year^{-1}, the value of the individual risk of an employee in the sulfur warehouse is 2.7×10-7 year^{-1}. This, according to the document "Methods for assessing the risks of emergencies and standards of acceptable risk of emergencies", approved by the First Deputy Minister of the Russian Federation for Civil Defense, Emergency Situations and Elimination of the Consequences of Natural Disasters of 09.01.2008 No. 1-4-60-9, corresponds to the zone of acceptable risk. However, to exclude (minimize) the possibility of an emergency in sulfur storage warehouses, it is necessary to introduce modern technical means of production, innovative technologies and additional organizational measures, such as:

— implementation of production control over the implementation of industrial safety requirements in accordance with the approved regulatory and legal acts;

— conducting training sessions and checking the readiness of working shifts for actions to prevent and eliminate emergencies;

— timely cleaning of the territories of the object and its surrounding areas from garbage and grass;

— implementation of recommendations in accordance with the "Information and technical handbook on the best available technologies" of 17.04.2019 No. 46-2019 Reduction of emissions of pollutants, discharges of pollutants during the stocking and storage of goods (cargo).

Conclusion. Thus, the task of minimizing the negative impact of the production activities of AO Ust-Donetsk Port on the environment is possible in the case of developing a set of environmental measures and industrial safety measures necessary for the organization of transit cargo handling, namely, rational methods of cargo handling, as well as improving the technology of their processing. To avoid the possibility of emergencies, it is necessary to introduce modern technical means of production, innovative technologies and additional organizational measures.

References

1. Bardyshev O. A., Bardyshev A. O. Obespechenie bezopasnosti pri perevalke sypuchikh gruzov v novykh morskikh terminalakh v Rossii [The security provision of bulk cargo handling at new sea terminals at Russia]. VESTNIK MANEB. 2019;24(1):5–11. (In Russ.)

2. Goncharova N. V. Obzor sovremennogo sostoyaniya tekhnicheskogo osnashcheniya rechnykh terminalov Rossii [Overview of the current state of technical equipment of river terminals in Russia]. Problemy ispol'zovaniya i innovatsionnogo razvitiya vnutrennikh vodnykh putey v basseynakh velikikh rek: tr. 19-go Mezhdunar. nauch.-prom. foruma "Velikie reki-2018" [Problems of the use and innovative development of inland waterways in the basins of great rivers: proc. of the 19-th International Scientific-Industrial Journal. forum "Great Rivers-2018"]. Nizhny Novgorod: Volga State University of Water Transport, 2018, iss. 7. 6 p. (In Russ.)

3. Meskhi B. Ch., Pustovaya L. E., Bogdanova I. V., Khlebunov S. A. Sovremennye problemy bezopasnosti: uchebnoe posobie [Modern safety problems: textbook]. Rostov-on-Don: DSTU Publishing house, 2011. 137 p. (In Russ.)

4. Pustovaya L. E., Meskhi B. Ch. Metody i pribory kontrolya okruzhayushchey sredy. Ekologicheskiy monitoring: uchebnoe posobie [Methods and devices for environmental monitoring. Environmental monitoring: textbook]. Rostov-on-Don: DSTU Publishing house, 2008. 218 p. (In Russ.)

5. Raanan R. et al. Elemental Sulfur Use and Associations with Pediatric Lung Function and Respiratory Symptoms in an Agricultural Community (California, USA). Environmental Health Perspectives. 2017;125(8):087007-1 087007-8. DOI: 10.1289/EHP528.

6. Zhang J. Factors influencing and a statistical method for describing dust explosion parameters: A review. Journal of Loss Prevention in the Process Industries. 2018;56:386-401. DOI: 10.1016/j.jlp.2018.09.005

7. Yanqiu Y.U. Research on explosion characteristics of sulfur dust and risk control of the explosion. Procedia Engineering. 2014;84:449 459. DOI: 10.1016/j.proeng.2014.10.455.

8. Min-Chi Wei, Yu-Chi Cheng, Yong-Ye Lin, Wen-Kai Kuo, Chi-Min Shu Applications of dust explosion hazard and disaster prevention technology. Journal of Loss Prevention in the Process Industries. 2020;68:104304. DOI: 10.1016/j.jlp.2020.104304.

9. Esipov Yu. V., Pustovaya L. E., Cheremisin A. I. Metody rascheta pokazatelei bezopasnosti i riska: uchebnoe posobie [Methods for calculating safety and risk indicators: textbook]. Rostov-on-Don: DSTU Publishing house, 2016. 87 p. (In Russ.)

10. Solovyeva V. G. K voprosu ob upravlenii riskami sovremennogo rechnogo porta [On the issue of risk management of a modern river port]. Modern High Technologies. Regional Application. 2012;3(31):59–66. (In Russ.)

11. Khoroshun E. G., Samchuk-Khabarova N. Ya., Esipov Yu. V. Razrabotka metodiki otsenivaniya granits priemlemogo professional'nogo riska [Development of the Methodology for the Limits of Acceptable Occupational Risk]. Occupational Safety in Industry. 2019;6:86–89. DOI: 10.24000/0409-2961-2019-6-86-89. (In Russ.)

12. Kukhta A. I., Mamatchenko N. S. Kompleksnyy metod otsenki stepeni professional'nykh riskov na predpriyatii [Integrated method of occupational risk degree assessment at the enterprise]. Safety of Technogenic and Natural Systems. 2019;1:18–27. DOI: 10.23947/2541-9129-2019-1-18-27 (In Russ.)

13. Esipov Yu. V., Shchekina E. V., Maslenskiy V. V. Primenenie logiko-vozmozhnostnogo metoda dlya ekspress-otsenki veroyatnosti proisshestviya v mnogofaktornoy tekhnicheskoy sisteme staleliteinogo tsekha [Application of logical-and-possibility method for rapid assessment of accident probability in a multivariable technical system of the steel foundry]. Safety of Technogenic and Natural Systems. 2018;3–4:52–63. (In Russ.)

Submitted 16.03.2021
Scheduled in the issue 14.04.2021

Authors:

Pustovaya, Larisa E., Associate Professor, Department of Life Safety and Environmental Protection, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Cand. Sci., Aassociate Professor, ORCID: https://orcid.org/0000-0002-3146-9819, lapus1@yandex.ru

Chebysheva, Valeriya A., Master's degree student, Department of Life Safety and Environmental Protection, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), ORCID: https://orcid.org/0000-0001-5417-2092 , chebysheva.valery@mail.ru

Contribution of the authors

L. E. Pustovaya — scientific supervision, formulation of the main concept, analysis of the research results, revision of the text, formulation of the conclusions; V. A. Chebysheva — collection of the initial data, formulation of the goal and objectives of the study, calculations, preparation of the text, development of the recommendations.

UDC 658.13 https://doi.org/10.23947/2541-9129-2021-2-50-57

Electronic control of the dispatch schedule as means of reduction of emissions of harmful substances by buses

S. I. Popov[1], G. A. Galchenko[1], Yu. V. Marchenko[1], D. S. Drozdov[2]

[1] Don State Technical University (Rostov-on-Don, Russian Federation)

[2] Southern Federal University (Rostov-on-Don, Russian Federation)

Introduction. Environmental contamination by vehicles is one of the main and important questions. Road transport is on the first place by quantity of harmful substances released into the atmosphere. The railway transportation pollutes environment by 3 %, planes — by 6 % from the total amount of pollution. The rest is motor transport. As it is known, the maximum quantity of harmful substances is thrown out in an idle mode of work of the engine, i.e. at idle times at stops. The improvement of an ecological situation on transport highways is possible by the optimization of movement of city public transport.

Problem Statement. The task was to develop a project that allows you to eliminate violations of the dispatch schedule of city buses. It is proposed to use the computer program "Line Dispatcher" developed by the authors and a mobile application to monitor the compliance with the dispatch schedule.

Theoretical Part. The field observations carried out on one of the most intense sections of the transport arteries of Rostov-on-Don — the ring at the intersection of Vavilova and Koroleva streets — show how many buses produce harmful emissions only on one section, stand idle at the stop, do not fulfill the dispatching schedule, and, thereby, worsen the environmental situation in the city. The authors have developed a computer program "Line Dispatcher", which allows you to: download a map of the city or a district, the information about the stops on the route and the timetable; choose the desired route; monitor the movement of the bus according to the schedule. The mobile app can be installed on any smartphone of the driver and dispatcher.

Conclusion. A practical solution is proposed to optimize the activity of public transport, which will eliminate downtime at stops due to electronic control of the dispatch schedule and reduce emissions of harmful substances by urban public transport.

Keywords: ecology, transport, polluting emissions, software product, mobile application.

For citation: Popov S. I., Galchenko G. A., Marchenko Yu. V., Drozdov D. S. Electronic control of the dispatch schedule as means of reduction of emissions of harmful substances by buses; Safety of Technogenic and Natural Systems. 2021;2:50–57. https://doi.org/10.23947/2541-9129-2021-2-50-57

Introduction. In modern society, the quality and reliability of vehicles is significantly increasing. At the same time, the intensity of traffic on the streets of large cities increases dramatically. Various solid, liquid and gaseous wastes in the form of sulfur, nitrogen, lead compounds, as well as soot and various hydrocarbons enter the atmosphere, water bodies, underground water and soil. The environmental situation is deteriorating as a result of the work of various transport complexes.

There are 110 city bus routes in Rostov-on-Don, and more than five hundred within the Greater Rostov agglomeration. In addition, more than 250 flights depart from Rostov to different cities. Despite the measures taken to protect the environment, the amount of emissions of pollutants into the atmosphere from motor vehicles increases by an average of 4.1% per year. As a result, in the Russian Federation, a huge amount of carcinogenic substances from motor vehicles enters the atmosphere every year: 29 thousand tons of benzene, 19.5 thousand tons of formaldehyde, 1.9 tons of benzpyrene and 7 thousand tons of lead. In general, the total amount of harmful substances emitted by cars annually exceeds the figure of 27 million tons [1-4].

Problem Statement. The field observations conducted on one of the busy sections of the transport arteries of Rostov-on-Don (the ring at the intersection of Vavilova and Koroleva streets) show that harmful emissions are produced by a large number of vehicles.

Field observations were carried out on various bus routes in order to record the real time of bus standing at bus stops. If the average standing time is 0.47 minutes, then at busy intersections, many buses are idle from 3.48 to 4.11 minutes or more. Drivers break the schedule, trying to land as many people in the bus as possible.

It is necessary, using modern digital technologies, to develop a project that allows you to eliminate violations of the schedule of city buses. To monitor the compliance with the dispatch schedule, it is proposed to use the Line Dispatcher computer program developed by the authors and a mobile application for this program.

Theoretical Part. On the section of the ring at the intersection of Vavilova and Koroleva streets, the field observations were carried out, which allowed us to analyze the transport situation, shown in Figures 1-2.

The observations were made on Monday, Wednesday and Friday in the morning from 7.30 am to 9.00 am and in the evening from 17.00 pm to 19.00 pm. Figure 1 shows the number of cars, trucks, and cyclists on the days and hours indicated above. Figure 2 shows the number of buses in the morning and evening hours.

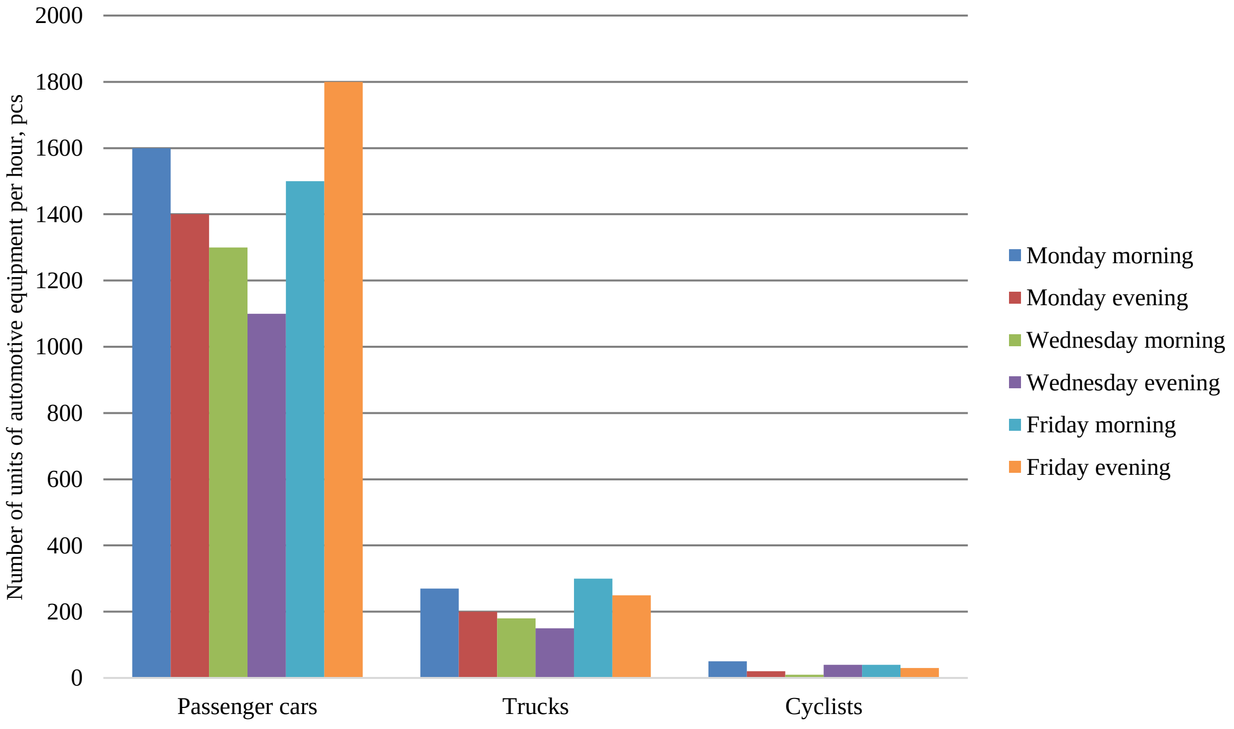


Fig. 1. Number of cars at the intersection of Vavilova and Koroleva streets

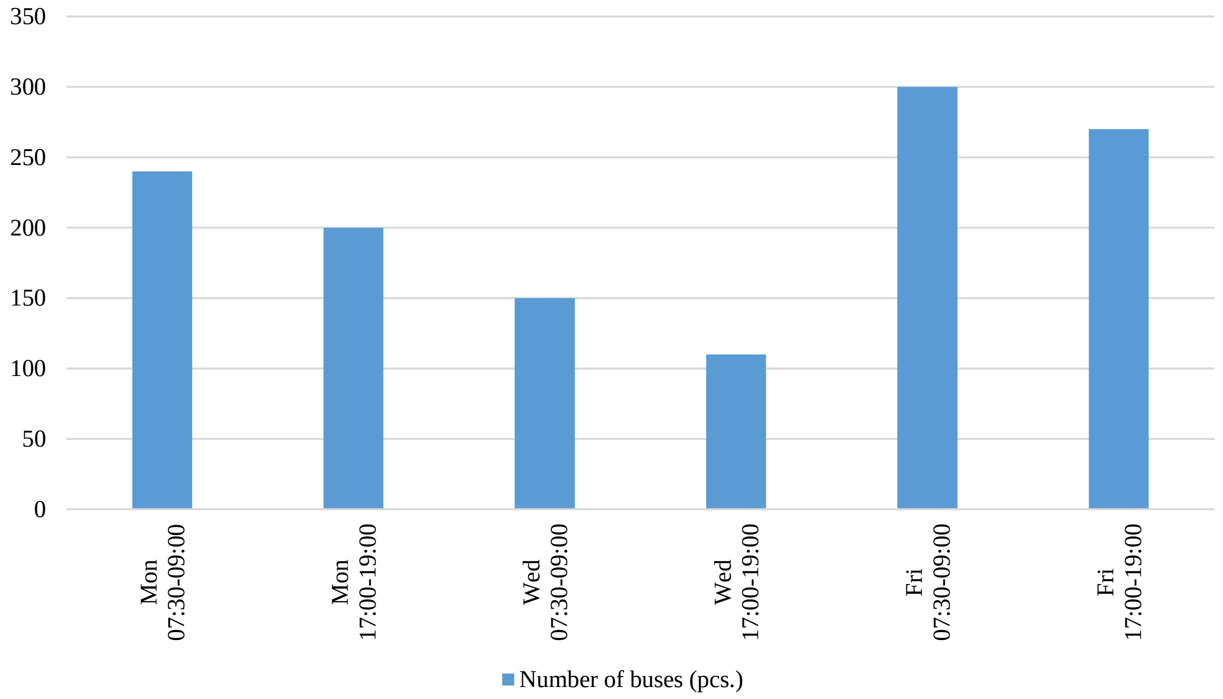


Fig. 2. Number of buses on the ring at the intersection of Vavilova and Koroleva streets in different time

The improvement of the environmental situation on transport highways is possible by optimizing the movement of urban public transport [5-12]. On the road, there are line dispatchers who should regulate traffic. According to the director of the Department of Transport of Rostov-on-Don, it is not yet possible to completely abandon the work of line dispatchers and switch to an electronic system for monitoring the traffic schedule. The only company that has managed to do this is the ATP-3. Buses of this company, following routes No. 96 and No. 94, run well-managed and without downtime.

In this paper, we propose a Line Dispatcher software package and a mobile application that can be installed on the phone of the driver and the dispatcher. This will allow the dispatcher to track the fulfillment of a schedule, eliminate long downtime at stops in the pursuit of profit.

Line Dispatcher software product. Taking into account the current situation with the movement of public transport in the city, a computer program in C++ is proposed that allows you to control the accuracy of the schedule on the route and replace line dispatchers.

The program allows you to:

— upload a map of the selected city or area;

— choose the desired route;

— read the information about the stops on this route from the database;

— download the schedule for this route;

— monitor the movement of the bus within the time frame of the schedule;

— inform the driver using the warning light (red or green) that it is still possible to stand at the stop or it is time to leave;

— send the information to the dispatcher.

Figure 3 shows the start menu of the program. You should select the bus route number from the vertical menu. After selecting the bus route number, a list of all stops of the selected route number is available (Fig. 4).

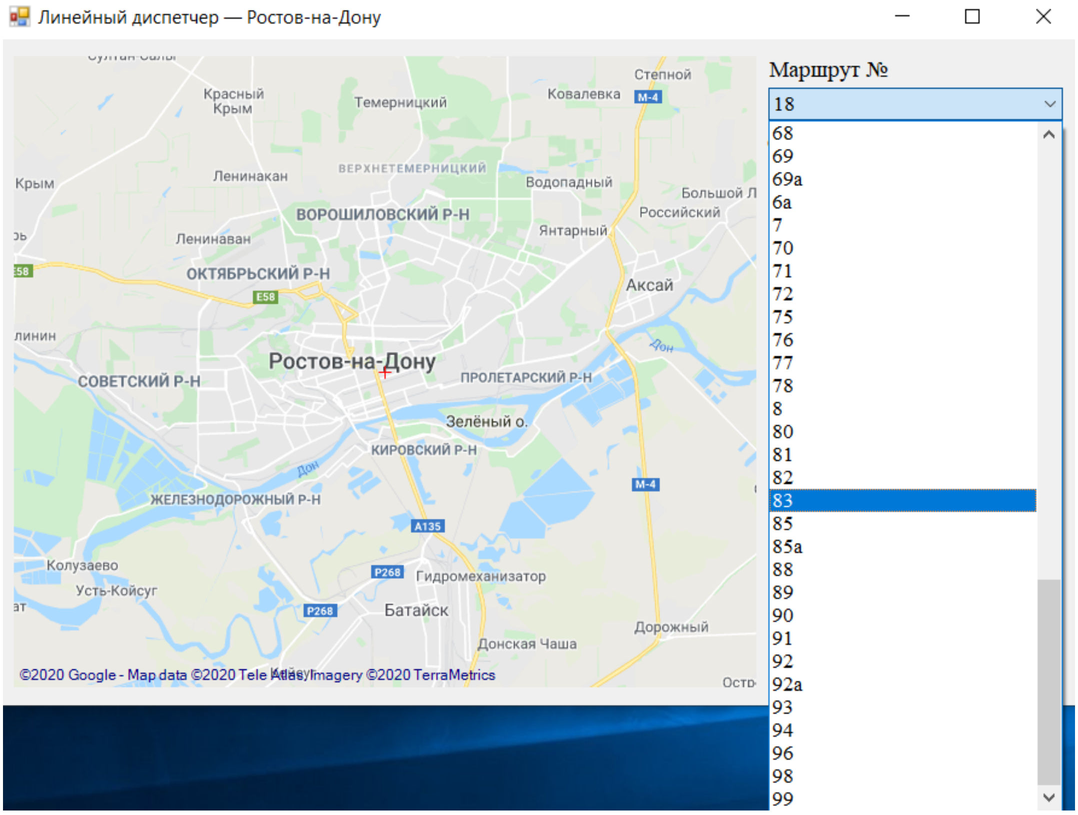
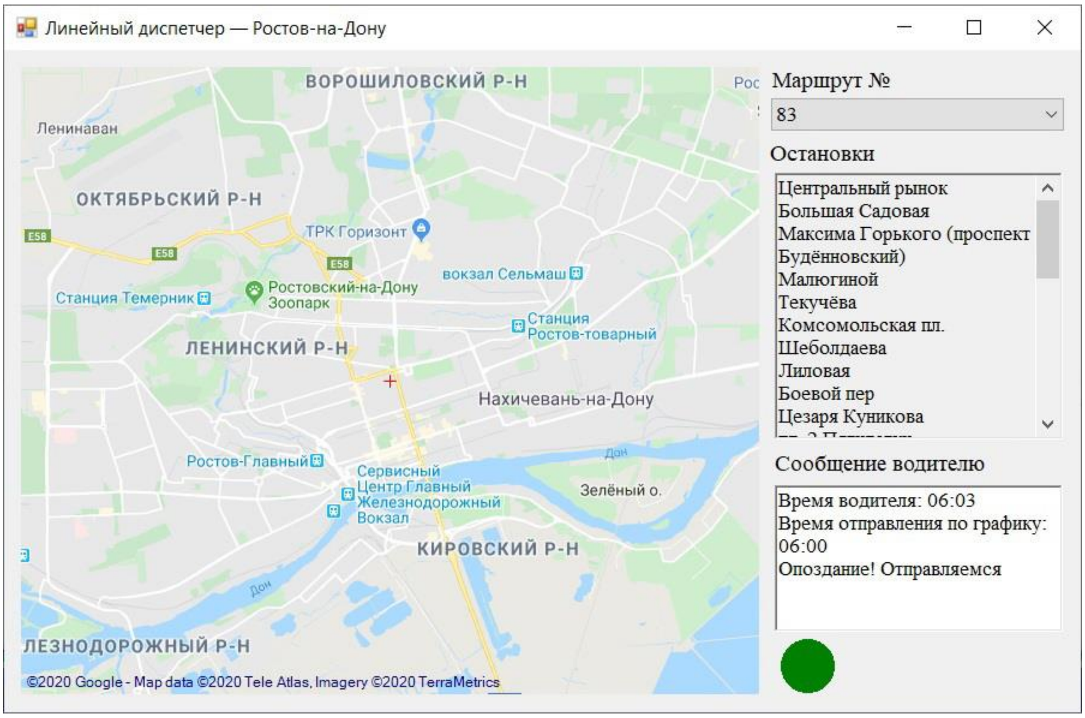

Линейный диспетчер — Ростов-на-Дону
Маршрут №
18
68
69
69а
6а
7
70
71
72
75
76
77
78
8
80
81
82
83
85
85а
88
89
90
91
92
92а
93
94
96
98
99
Ростов-на-Дону
©2020 Google - Map data ©2020 Tele Atlas, Imagery ©2020 TerraMetrics

Fig. 3. Program menu with a map of the selected city and bus route numbers


Линейный диспетчер — Ростов-на-Дону
Маршрут №
83
Остановки
Сообщение водителю
©2020 Google - Map data ©2020 Tele Atlas, Imagery ©2020 TerraMetrics

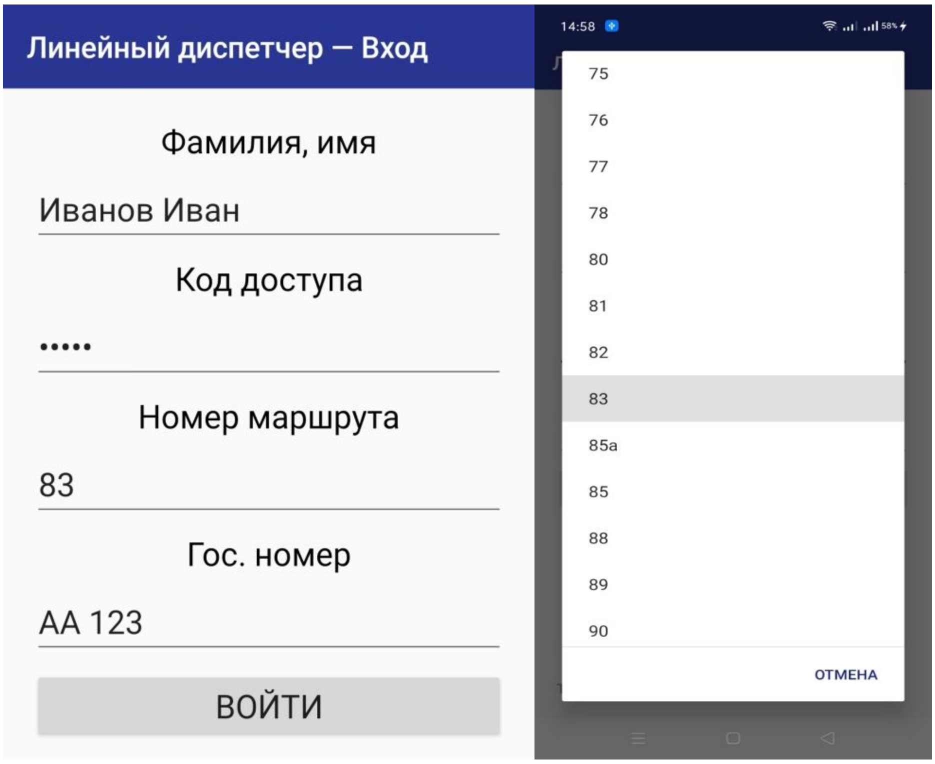
Центральный рынок
Большая Садовая
Максима Горького (проспект Будённовский)
Малюгиной
Текучёва
Комсомольская пл.
Шеболдаева
Липовая
Боевой пер
Цезаря Куникова

Время водителя: 06:03
Время отправления по графику: 06:00
Опоздание! Отправляемся

Fig. 4. Program window with a map of the city and the stops on the selected route

The "Message to the driver" window displays information about following the schedule. There are two possible situations: moving ahead and lagging behind. The program window in both cases is shown below.

Mobile application for communication between the driver and the dispatcher. To ensure the compliance with the traffic schedule on the route, eliminate downtime at stops and congestion of transport at bus stops, a mobile application has been developed. The mobile app can be installed on any smartphone of the driver and the dispatcher. After receiving the message about a violation of the traffic schedule, the dispatcher can contact the driver and find out the reasons. The driver can also contact the dispatcher. In addition, in case of a violation of the traffic schedule, messages can be automatically sent to the dispatcher. Before the start, the driver or the dispatcher opens a window with a form to log in. You must fill in all the fields. After filling in the fields, as well as the information about the driver on this route, a list of bus numbers in the city appears. Figure 5-6 show screenshots of the application running on the Android OS.



Линейный диспетчер — Вход

Фамилия, имя
Иванов Иван

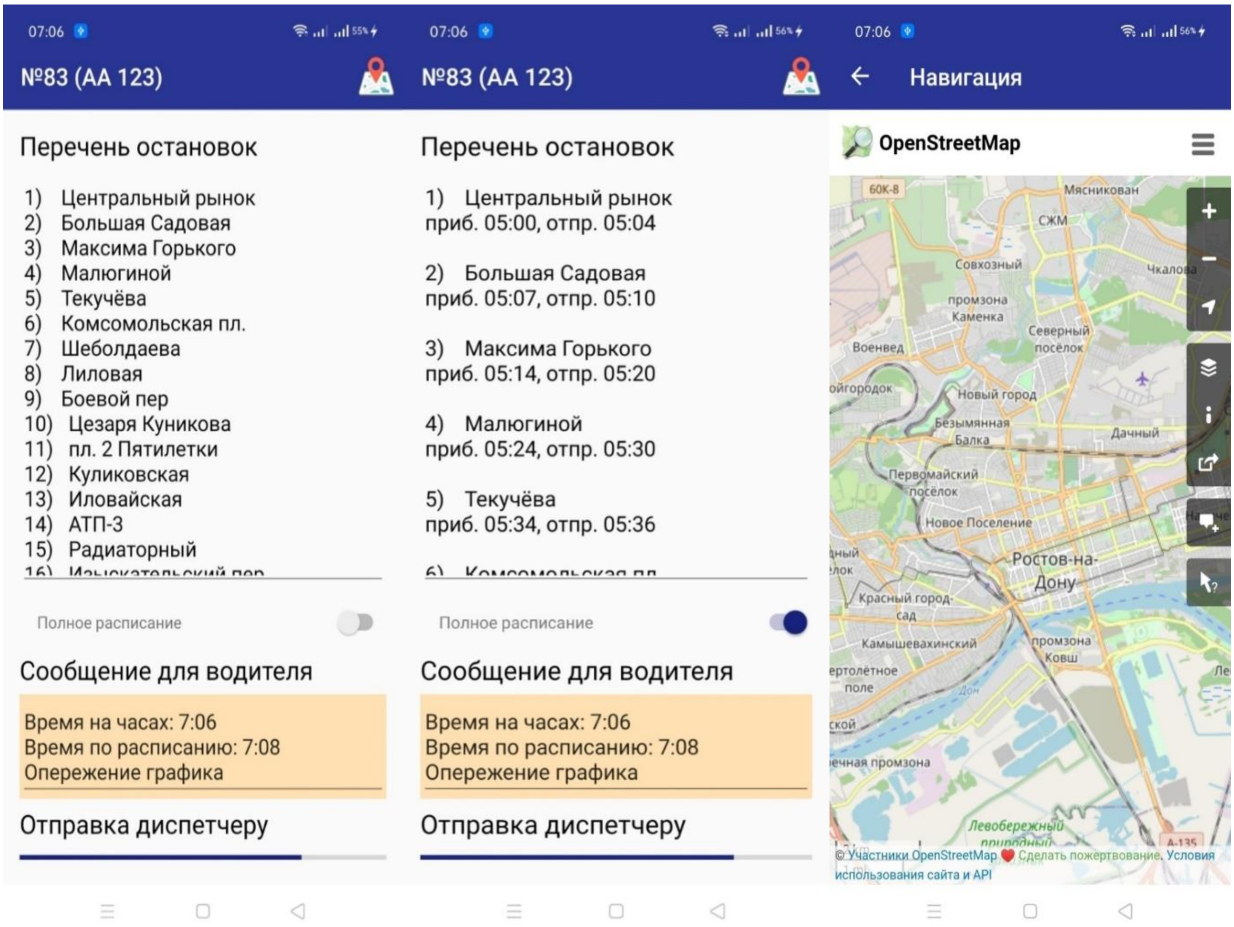
Код доступа
•••••

Номер маршрута
83

Гос. номер
АА 123

Fig. 5. Mobile app start menu and a list of city buses

Description of the program. The mobile app is written in C# using cross-platform Xamarin.Forms technology, which allows you to run the program on any smartphone. After entering the application, the main window of the program opens, which displays a list of stops and displays a message to the driver about the compliance with the schedule (Fig. 6 a and 6 b) and a map of the city (Fig. 6 c).



№83 (АА 123)

Перечень остановок

1) Центральный рынок
2) Большая Садовая
3) Максима Горького
4) Малюгиной
5) Текучёва
6) Комсомольская пл.
7) Шеболдаева
8) Лиловая
9) Боевой пер
10) Цезаря Куникова
11) пл. 2 Пятилетки
12) Куликовская
13) Иловайская
14) АТП-3
15) Радиаторный

Полное расписание

Сообщение для водителя

Время на часах: 7:06
Время по расписанию: 7:08
Опережение графика

Отправка диспетчеру

№83 (АА 123)

Перечень остановок

1) Центральный рынок
приб. 05:00, отпр. 05:04

2) Большая Садовая
приб. 05:07, отпр. 05:10

3) Максима Горького
приб. 05:14, отпр. 05:20

4) Малюгиной
приб. 05:24, отпр. 05:30

5) Текучёва
приб. 05:34, отпр. 05:36

Полное расписание

Сообщение для водителя

Время на часах: 7:06
Время по расписанию: 7:08
Опережение графика

Отправка диспетчеру

Навигация

a) *b*) *c*)

Fig. 6. Traffic schedule: a — list of stops and a message to the driver and the dispatcher; b — list of stops with the time of arrival at the stop and the time of departure; c — navigation on the map of the mobile application

All messages are sent to the dispatcher. The schedule delay is marked in red, and the lead is yellow, so that the driver can quickly navigate by color.

Conclusion. Modern society needs a constant increase in the volume of transport communication, improving its reliability, safety and quality. This requires the increase in the cost of improving the infrastructure of the transport network, turning it into a flexible, highly managed logistics system. The algorithm is proposed and the Line Dispatcher program is developed. The program allows you to choose any route in Rostov-on-Don, download the data about bus stops and travel time on the route. The program monitors the progress of the driver's schedule and informs him about the violations in the form of a text message and a color signal. A mobile application for the driver and the dispatcher has been developed. The mobile application is written on a cross-platform basis, which allows you to install it on any smartphone. The implementation of this development will help to optimize the movement of public transport and improve the environmental situation.

References

1. Meskhi B., Golev B., Efros V., Rudoy D., Olshevskaya A., Zhurba V., Chayka Y., E3S Web of Conferences, 2019;135:01083. DOI: 10.1051/e3sconf/201913501083

2. Altybayev A., Zhanbyrbayev A., Meskhi B., Rudoy D., Olshevskaya A., Prohorova A. E3S Web of Conferences, 2019;35:01078. DOI: 10.1051/e3sconf/201913501078

3. Kuren S. G., Galchenko G. A. Modelirovanie transportnykh potokov: monografiya [Modeling of transport flows: monograph]. Moscow: Pero, 2020. 168 p. (In Russ.)

4. Kuren S. G., Popov S. I., Dontsov N. S., Zubareva E. G. Evolyutsiya khimicheskogo sostava vybrosov zagryaznyayushchikh veshchestv v atmosferu v gorode-millionnike [Evolution of the chemical composition of emissions of pollutants into the atmosphere in the city]. Engineering journal of Don. 2018;2:133. (In Russ.)

5. Zyryanov V. V. Rukovodstvo po modelirovaniyu dorozhnogo dvizheniya: ucheb. pos. [Manual for road traffic modeling: textbook.]. Rostov-on-Don: Rostov State University of Civil Engineering, 2015. 61 p. (In Russ.)

6. Nikolaev N. N., Marchenko Yu. V., Filatov S. K. Research and modeling of the taxi service in small towns. International Scientific Conference «Construction and Architecture: Theory and Practice of Innovative Development» (CATPID-2019): IOP Conference Series: Materials Science and Engineering, 2019, 698 p. DOI: 10.1088/1757-899X/698/6/066027

7. Ilyasov V., Meshi B., Pham D., Nguyen C., Holodova O., Zhdanova T., Ershov I., Prutsakova N., Popova I. Springer Proceedings in Physics. 2018;207:127-144. DOI: 10.1007/978-3-319-78919-4.

8. Korotky A. A., Marchenko E. V., Popov S. I., Marchenko Ju. V., Dontsov N. S. Theoretical foundations of modeling the process of transport vehicles steel ropes structural defects formation. XIII International Scientific and Practical Conference «State and Prospects for the Development of Agribusiness – INTERAGROMASH 2020». E3S Web of Conferences. 2020;175:05018. DOI: 10.1051/e3sconf/202017505018

9. Korotkiy A. A., Galchenko G. A., Ivanov V. V. Informatsionno-kommunikatsionnaya logisticheskaya sistema dlya optimizatsii transportnykh marshrutov v urbanizirovannoy srede [Information-communication logistic system for transport routes optimization in urbanization environment]. Vestnik Bulletin of Bryansk State Technical University. 2018;4(65):63–67. (In Russ.)

10. Kushchenko S. V. Povyshenie effektivnosti organizatsii dvizheniya na osnove modelirovaniya transportnykh potokov: dis. … kand. tekhn. nauk [Improving the efficiency of traffic management based on traffic flow modeling: author’s thesis]. Kursk, 2012. 134 p. (In Russ.)

11. Fialkin V. V., Kolesnikov E. I. Modelirovanie transportnogo sprosa v g. Rostov-na-Donu dlya izucheniya nagruzki na dorozhnuyu set' [Traffic demand’s simulation in Rostov-on-Don to study the road network load]. Young Researcher of the Don. 2020;5:65–69. (In Russ.)

12. Yakimov M. R. Transportnoe planirovanie: sozdanie transportnykh modeley gorodov [Transport planning: creating transport models of cities]. Moscow: Logos, 2013. 188 p. (In Russ.)

Submitted 30.03.2021

Scheduled in the issue 27.04.2021

Authors:

Popov, Sergey I., Associate Professor, Department of Operation of Vehicles and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Cand. Sci., Associate Professor, ORCID https://orcid.org/0000-0002-8538-9478 , spopov1957@yandex.ru

Galchenko, Galina A., Associate Professor, Department of Operation of Vehicles and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Cand. Sci., Senior Researcher, ORCID: https://orcid.org/0000-0001-5966-0423 , ggalchenko@inbox.ru

Marchenko, Yulianna V., Associate Professor, Department of Operation of Vehicles and Logistics, Don State Technical University (1, Gagarin sq., Rostov-on-Don, RF, 344003), Cand. Sci., ORCID: https://orcid.org/0000-0001-7600-492X , marchenko-6470@mail.ru

Drozdov, Dmitriy S., Student, Department of Computer Science and Computing Experiment, Southern Federal University (8-a, Milchakova st., Rostov-on-Don, RF, 344090), ORCID: https://orcid.org/0000-0003-0381-1012, ds-drozdov@yandex.ru

Contribution of the authors:

S. I. Popov — formulation of the main concept, correction of the conclusions; G. A. Galchenko — formulation of the main concept, goals and objectives of the study, development of the algorithm, analysis of the research results, revision of the text, correction of the conclusions; Yu. V. Marchenko — field observations, development of the algorithm; D. S. Drozdov — software implementation in C++ of the program "Linear Dispatcher" and the mobile application.